HUMAN

PHYSIOLOGY.

HUMAN PHYSIOLOGY.

BY

ROBLEY DUNGLISON, M.D., LL.D.,

PROFESSOR OF THE INSTITUTES OF MEDICINE IN JEFFERSON MEDICAL COLLEGE, PHILADELPHIA;
VICE-PRESIDENT OF THE AMERICAN PHILOSOPHICAL SOCIETY, ETC. ETC.

"Vastissimi studii primas quasi lineas circumscripsi."—HALLER.

WITH

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HUMAN PHYSIOLOGY.

BOOK II.

ANIMAL FUNCTIONS.

CHAPTER I.

SENSIBILITY.

(*CONTINUED.*)

D. SENSE OF HEARING OR AUDITION.

Audition makes known to us the peculiar vibrations of sonorous bodies, that constitute *sounds*. It differs from the senses which have already been described, in the fact, that contact is not required between the organ of sense and the sonorous body; or between it and any emanation from that body. It is, however, a variety of touch, but produced by a medium acted upon by the vibratory body.

1. ANATOMY OF THE ORGAN OF HEARING.

The auditory apparatus is a subject of intricate study to the young anatomist; and unfortunately when he has become acquainted with the numerous minute portions to which distinct and difficult appellations have been appropriated, he has, as in many other cases, attained a tedious detail of names, without having added to his stock of physiological information. Happily, it is not necessary for our purpose to go so minutely into the description of the organ of hearing. According to the plan hitherto pursued, allusion will be made to those portions only that concern the physiological inquirer.

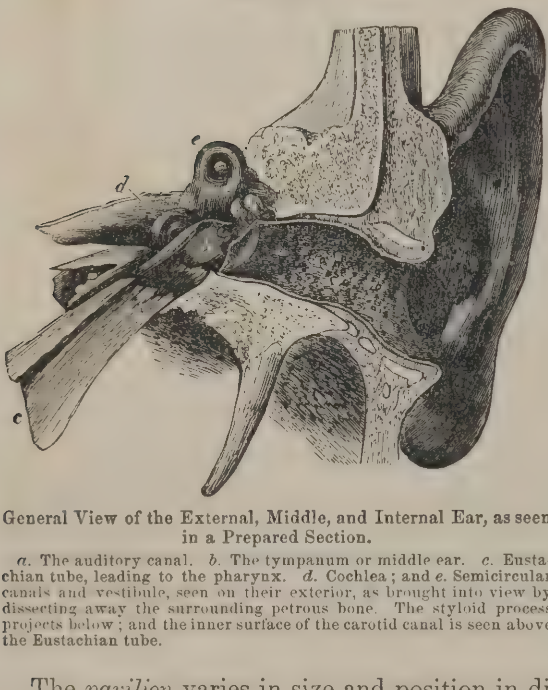
In the ear, as well as in the eye, we have the distinction between the physical and nervous portions of the organ more clearly exhibited than in the skin, mouth, or nose. The nervous portion is situate deeply within the organ; and the parts between it and the exterior act physically—on sonorous vibrations, in the case of the ear; and on light, in that of the eye.

The organs of the senses hitherto considered are symmetrical. Those of audition are two in number, distinct but harmonious, and situate at the sides of the head, in a part of the temporal bone, generally called, from its hardness, *pars petrosa*, and by the French and German anato-

mists regarded as a distinct bone, under similar appellations—*Le Rocher*, and Felsenbein, ("rockbone.") This bone is seated at the base of the skull, so that the internal parts of the auditory organ are deeply and securely lodged.

For facility of description, the ear may be divided into three portions: — 1. *External ear* or that exterior to the membrana tympani; 2. *Middle ear*—the space contained between the membrana tympani and internal ear; and 3. *The internal ear* in which the auditory nerve is distributed.

Fig. 246.



General View of the External, Middle, and Internal Ear, as seen in a Prepared Section.

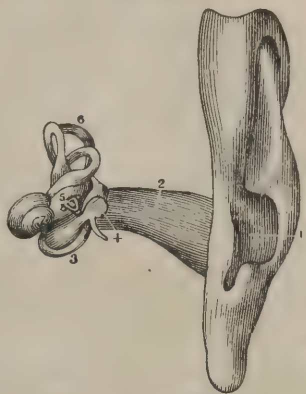
a. The auditory canal. *b.* The tympanum or middle ear. *c.* Eustachian tube, leading to the pharynx. *d.* Cochlea; and *e.* Semicircular canals and vestibule, seen on their exterior, as brought into view by dissecting away the surrounding petrous bone. The styloid process projects below; and the inner surface of the carotid canal is seen above the Eustachian tube.

1. *External ear.* This portion of the auditory apparatus is commonly looked upon as an acoustic instrument, for collecting the sonorous rays or vibrations, and directing them, in a concentrated state, to the parts within. It is composed of the *pavilion*, and *meatus auditorius externus*.

The *pavilion* varies in size and position in different individuals. It is the fibro-cartilaginous, thin, expanded portion, which is an appendage, as it were, to the head. It is irregular on its anterior surface; presenting several eminences and depressions. The eminences are five in number; and have been called, by anatomists, *helix*, *anthelix*, *tragus*, *antitragus* and *lobe*. The *helix* forms the rim of the pavilion: the *tragus* is the small nipple-like projection on the facial side of the meatus auditorius; the *antitragus* is the projection opposite to this,—forming the lower portion of the *anthelix;* and the *lobule* is the fatty, pendulous portion, to which ear-rings are attached. The depressions are three in number—the *groove of the helix* or *cavitas innominata; the fossa navicularis* or *scapha;* and the *concha.* The name of the first sufficiently indicates its situation; the second is nearer the meatus auditorius; and the third is the expanded portion, which joins the commencement of the meatus, and is bounded by the anthelix, tragus, and antitragus. The pavilion is supple and elastic; and, beneath the skin are numerous sebaceous follicles, which are distinctly perceptible, and give the skin its polish, and probably a portion of its suppleness. On the different eminences, some muscular fibres are perceptible, which it is not necessary, for our purpose, to distinguish; for in man at least

they are but *vestiges*—as the French term them—to indicate the uniform plan that appears to have prevailed in the formation of vertebrated animals: if they have any office it must be unimportant. Numerous vascular and nervous ramifications are distributed on the pavilion. It is attached to the head by different ligaments, called—from their situation or attachments—*zygomato-auricular* or *anterior-auricular*:—*tempero-auricular* or *superior-auricular*, and *mastoido-auricular* or *posterior-auricular*; all of which terminate on the convex part of the concha. Three muscles, in animals at least, are attached to the ear to move the pavilion. These occupy the same position as the ligaments described; and have similar names. In man, they, again, are mere *vestiges*; but in many animals—as the horse—they are largely developed, and capable of moving the pavilion in various directions; and there are persons, who possess a degree of voluntary power over it.

Fig. 247.



Anterior View of the External Ear, as well as of the Meatus Auditorius, Labyrinth, &c.

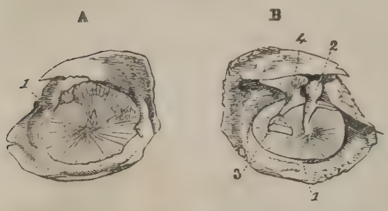
1. The opening into the ear at the bottom of the concha. 2. Meatus auditorius externus or cartilaginous canal. 3. Membrana tympani stretched upon its ring. 4. Malleus. 5. Stapes. 6. Labyrinth.

The *meatus auditorius externus* extends from the inner extremity of the concha to the membrana tympani. In the adult, it is about an inch long; narrower in its middle than extremities; longer inferiorly than superiorly, owing to the obliquity of the membrana tympani; and slightly curved upwards about its middle. The outer orifice is furnished with down or hairs—*vibrissæ*—like the orifices of certain other canals. The meatus is osseous, for the space of half an inch, and penetrates the temporal bone. More externally, it is formed of fibro-cartilage,—a prolongation of that of the concha. It is lined by an extension of the skin, which becomes gradually thinner as it proceeds inwards, and is ultimately reflected over the outer surface of the membrana tympani. Beneath this skin, numerous sebaceous glands or follicles are situate, which secrete the bitter humour, called *cerumen*. This humour occasionally becomes inspissated; obstructs the canal; prevents sonorous vibrations from reaching the membrana tympani, and is thus the cause of deafness. Softening it, by means of warm water or oil, or soap and water dropped into the meatus, and removing it by means of the syringe, restores the hearing.

The portion of the auditory apparatus arbitrarily termed the *external ear* is a complete *cul-de-sac*, formed by a prolongation of the common integument. There is no opening communicating with the next portion—the middle ear; the *membrana tympani*, with its dermoid envelope, forming at once the medium of union and separation between the two. A knowledge of this fact would somewhat diminish the alarm in cases where insects or other extraneous bodies get into the meatus. The pain is excruciating, owing to the great general sensibility of this portion of the auditory apparatus; but the chief dread entertained is, that the irritating substance may pass into the head. It

cannot proceed further than the membrana tympani, and even if it were able to clear this obstacle, insuperable impediments would exist to its farther progress inwardly.

Fig. 248.



Membrana Tympani from the outer (A) and from the inner (B) sides.

1. Membrana tympani. 2. Malleus. 3. Stapes. 4. Incus.

2. The *middle ear* includes the cavity of the tympanum, the small bones contained in the cavity, the mastoid cells, Eustachian tube, &c. Like the last, it belongs to the physical portion of the ear. The *cavity of the tympanum* or *drum of the ear* has the shape of a portion of an irregular cylinder. Its name is, indeed, not inappropriate. It bears some resemblance to a drum; not only in form, but, as will be seen, in function. The outer extremity is closed, as in a drum, by the *membrana tympani*. This membrane is not situate vertically in the meatus; but obliquely downwards and inwards; so that the cavity is broader above than below. It is very thin and transparent, and consists of three layers, the outermost formed by the membrane lining the meatus auditorius externus; the innermost belonging to the membrane of the cavity of the tympanum; and the middle the membrane proper. On its inner side passes the nerve called *chorda tympani;* and its centre affords attachment to one extremity of the chain of small bones,—to the handle of the *malleus*. The proper tissue of the membrane is dry, and it is generally esteemed to be devoid of fibres, vessels, and nerves. Sir Everard Home,[1] however, asserts, that it is muscular; that its fibres run from the circumference towards the centre, and are attached to the malleus; and that if the membrane of the human ear be completely exposed on both sides by removing the contiguous parts, the cuticular covering be washed off from its external surface, and it be placed in a clear light, the radiated direction of its fibres may be easily detected. This fibrous arrangement, Sir Everard conceives to be muscular, and on this he founds some ingenious speculations, to be hereafter noticed, regarding the appreciation of sounds. The discovery of a fibrous structure would, however, by no means prove, that the membrane is capable of contracting; or that it is formed of muscular tissue. Many ligaments, which consist of gelatin, and are, consequently, not contractile like muscles, are distinctly fibrous in their arrangement. The same may be said of tendons, whose utility, as conductors of force developed by muscle, would be materially interfered with, were they possessed of contractility. No muscular fibres have, however, been detected in the membrane by histologists. Again:—Messrs. Ruysch,[2] Sir Everard Home, and Sir Charles Bell,[3] affirm, that the membrane is vascular,—Sir Everard asserting, that the vessels, in their distribution, resemble those of the iris, and are

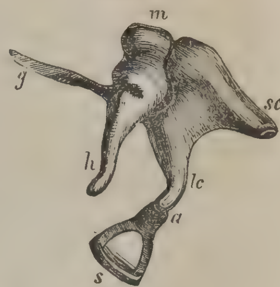
[1] Philos. Transact. for 1800, P. i. p. 1, and Lectures on Comp. Anat., iii. 262, Lond., 1823.

[2] Epist. Anat. octava, p. 10, Amstel., 1724.

[3] Anat. and Physiol., edited by J. D. Godman, 5th Amer. edit., ii. 253, New York, 1827.

nearly half as numerous;—their general direction being from the circumference to the handle of the malleus. It is not easy to account for this discrepancy amongst practical anatomists as to the structure of the membrane. A part of it is probably referable to some having directed their attention to the membrane proper; and others to the membrane with its dermoid coverings, which are highly vascular.

Fig. 249.



Ossicles of the left Ear articulated, and seen from the outside and below.

m. Head of the malleus below which is the constriction, or neck. *g*. Processus gracilis, or long process, at the root of which is the short process. *h*. Manubrium, or handle. *sc*. Short crus; and *lc*, long crus of the incus. The body of this bone is seen articulating with the malleus, and its long crus, through the medium of the orbicular process, here partly concealed, *a*, with the stapes. *s*. Base of the stapes.—Magnified three diameters.

The inner extremity of the drum is partly osseous, partly membranous. Nearly opposite the centre of the membrana tympani is the *foramen ovale* seu *vestibulare*, called, also, the *fenestra ovalis* seu *vestibularis*, situate vertically, and forming a communication between the middle and internal ear. It is closed by a membrane—consisting, like the membrana tympani, of three layers—to which is attached the base of the stapes, the inner extremity of the chain of ossicles that stretches across the cavity. Immediately below the foramen ovale is the bony projection called the *promontory;* and beneath this, again, a second opening, called *foramen rotundum* seu *cochleare*, and *fenestra rotunda* seu *cochlearis*, which forms a communication between the middle ear and the external scala of the cochlea. This foramen is closed by a membrane, similar to that of the foramen ovale; not, like it, parallel, or nearly so, to that of the tympanum,—but situate obliquely. There is no communication by a chain of bones between it and the membrana tympani.

The *small bones* or *ossicles* are four in number, so connected with each other as to form a bent lever; one extremity of which is attached to the tympanic surface of the membrana tympani,—the other to the membrane of the foramen ovale. These bones are usually termed, from their shape—beginning with the most external, and following their order—*malleus*, *incus*, *os orbiculare* (by some not considered a distinct bone, but a process of the incus,) and *stapes*. A small muscular apparatus,—consisting of three muscles, *anterior muscle of the malleus; internal muscle* of the same bone; and *muscle of the stapes—stapedius*—is attached to the chain, which it can stretch or relax; and, of course, it produces a similar effect upon the membranes to which the chain is attached. Bellingeri[1] thinks, that the fifth pair regulates altogether the involuntary motions of the middle ear.

At the anterior and inferior part of the cavity is the tympanic extremity of a canal, through which the drum receives the air it contains. This canal, called *Eustachian tube*, is about two inches long, and proceeds obliquely forwards and inwards from the middle ear to the

[1] Edinb. Medical and Surgical Journal, July, 1834, p. 128.

lateral and superior part of the pharynx, into which it opens behind the posterior nares. It is partly osseous, partly fibro-cartilaginous and membranous; and, towards its pharyngeal extremity, expands, terminating by an oval aperture resembling a cleft. Throughout its course it is lined by a mucous membrane, which appears to be a prolongation of that of the nasal fossæ, and is capable of being more or less contracted and expanded by the muscles, which compose and move the velum palati. The cavity of the tympanum communicates, by a short and ragged canal, with numerous cells contained in the mastoid process. These cells open into each other, and vary in number, size, and arrangement in different individuals, and animals. They are called *mastoid cells.* The cavity of the tympanum is larger in animals whose sense of hearing is most acute. In man, it is about a quarter of an inch deep, and half an inch broad, and is lined by a prolongation of the same membrane as that which lines the Eustachian tube. This membrane, as we have seen, covers the membrana tympani, and the membranes of the foramen ovale, and foramen rotundum. It likewise lines the mastoid cells, and is reflected over the small bones.

Fig. 250.

Labyrinth separated from the solid bone in which it lies embedded.

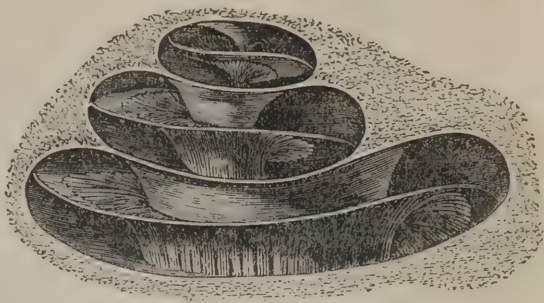
V. Vestibule. X, Y, Z. Semicircular canals. K. Cochlea. O. Fenestra ovalis. R. Fenestra rotunda.

The middle ear does not exist in every animal endowed with hearing. It does not begin to appear lower in the scale than reptiles; and is by no means equally complex in all. Frequently, the chain of bones is entirely wanting; and at other times we find one bone only.

3. The *internal ear* or *labyrinth* is the most important part of the apparatus. It consists of several irregular cavities in the pars petrosa of the temporal bone, in which the nerve of audition is distributed. It is, consequently, here that the physical part of audition terminates, and the nervous begins. The labyrinth comprises the *vestibule*, *semicircular canals*, and *cochlea.* The *vestibule*—as its name imports—is the hall, that communicates with all the other cavities of the labyrinth. It would appear to be the most essential part of the organ, as it often exists alone. At its inner surface are numerous small foramina, which communicate with the bottom of the meatus auditorius internus, and through which the filaments of the auditory nerve reach the labyrinth. Externally, it communicates with the cavity of the tympanum by the foramen ovale. Posteriorly, it opens into the semicircular canals by five foramina; and anteriorly, by a single foramen, into the internal scala of the cochlea. There is, also, posteriorly and inferiorly, near the common orifice of the two vertical semicircular canals, the opening of a small, bony duct, which terminates internally at the posterior surface of the petrous portion of the temporal bone. This duct is called *aquæductus* seu *diverticulum vestibuli.* The *semicircular canals* are three in number, and occupy the hinder part of the labyrinth. They are called *superior vertical*, *poste-*

rior vertical, and *horizontal*. They are cylindrical cavities, curved semicircularly, and are more expanded at their vestibular origin, which has been, therefore, called *ampulla*. They are constituted of a plate of bone, situate in the spongy tissue of the pars petrosa, and all of them communicate with the vestibule. The *cochlea* is the most anterior portion of the labyrinth. It is so called in consequence of its resemblance—in man and mammalia — to a snail's shell; hence, also, its French and German names, *limaçon*, and Schnecke. It is the most intricate part of the organ of hearing, and does not admit of easy description. It is a conoidal canal, spirally convoluted, making two turns upon itself, and resting on a bony nucleus or pillar, called *modiolus*. The base of the nucleus is concave; corresponds to the bottom of the meatus auditorius internus, and is pierced by small foramina, through which the filaments of the auditory nerve reach the cochlea. The spiral canal is divided, in its whole length, by a partition, half osseous and half membranous, called *lamina spiralis;* so that two distinct tubes are thus formed. These are the *scalæ of the cochlea*. At the apex of the cochlea they run into each other by an opening termed by M. Breschet *helicotrema;* and at the base, the one turns into the vestibule, and is hence called *superior* or *vestibular* or *internal scala;* the other communicates with the cavity of the tympanum by the foramen rotundum, and is called *inferior*, *tympanic*, or *external scala*. At this scala, near the foramen rotundum, a bony canal begins, which proceeds towards the posterior surface of the pars petrosa, on which it opens. It is *aquæductus* seu *diverticulum cochleæ*. The cochlea does not exist in all animals that hear. It is not, therefore, of essential importance. It varies, too, greatly, in complication, in different animals. In birds, whose hearing is extremely delicate, it merely consists of a short, hollow, bony process, divided into two scalæ but without any spiral arrangement. In reptiles, it is still more imperfect; and in many species can scarcely be said to exist. In fishes there is no trace of it.

Fig. 251.



Cochlea of a new-born Infant, opened on the side towards the Apex of the Petrous Bone.

It shows the general arrangement of the two scalæ, the lamina spiralis, and the distribution of the cochlear nerve. At the apex is seen the modiolus expanding into the cupola, where the spiral canal terminates in a cul-de-sac. The helicotrema is not visible in this view.

The different cavities of the internal ear are lined by an extremely delicate membrane. In many animals this membrane exists alone, without any bony parietes. It exhales at its inner surface a limpid fluid, called *liquor* or *lymph* of Cotugno or Cotunnius, *perilymph* of Breschet, which, under special circumstances, can reflow into the aquæductus vestibuli and aquæductus cochleæ. This fluid is contained in all the cavities of the internal ear. Within that of the osseous laby-

Fig. 252.

Interior of the Osseous Labyrinth.

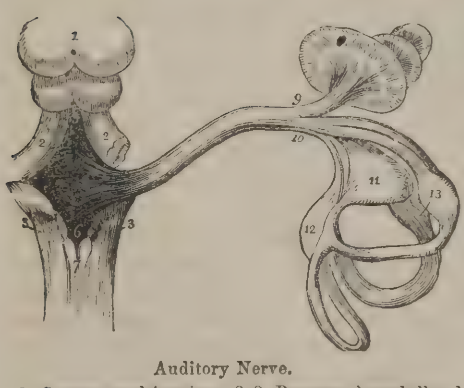
V. Vestibule. *av.* Aqueduct of the vestibule. *o.* Fovea semi-elliptica. *r.* Fovea hemispherica. S. Semicircular canals. *s.* Superior. *p.* Posterior. *i.* Inferior. *a, a, a.* The ampullar extremity of each. C. Cochlea. *ac.* Aqueduct of the cochlea. *sv.* Osseous zone of the lamina spiralis, above which is the scala vestibuli, communicating with the vestibule. *st.* Scala tympani below the spiral lamina.

Fig. 253.

Membranous Labyrinth of the Left Side, with its Nerves and Otoliths.

su. Superior semicircular canal, with the ampulla and its nerve at one end, and the other end joined by *p*, the posterior canal, to form the *tubulus communis*. *i.* Inferior or horizontal canal, with the ampulla and its nerve at one end, and the other entering the utriculus separately. *c.* Powdery otolith seen through the translucent wall of the common sinus or utriculus, with the nerves distributed to it. *s.* Powdery otolith of the sacculus seen with its nerve, in a similar way. *n.* Cochlear division of the auditory nerve, cut off where it enters the cochlea. *d. Portio dura* of the seventh pair leaving the auditory nerve, or *portio mollis*, to enter the aqueduct of Fallopius. Magnified.

Fig. 254.



Auditory Nerve.

1. Corpora quadrigemina. 2, 2. Processus è cerebello ad testes. 3, 3. Corpora restiformia. 4. Fourth ventricle. 5. Iter a tertio ad quartum ventriculum. 6. Calamus scriptorius. 7. Posterior median columns of spinal cord forming by their divergence the point of the calamus, also called *ventricle of Arantius*. 8. Lines of origin of fourth ventricle, and of auditory nerve. 9. Anterior branch distributed to cochlea. 10. Posterior or vestibular branch. 11. Utriculus communis concealing sacculus proprius from view. 12. Ampulla of oblique semicircular canal. 13. Ampullæ of perpendicular and horizontal semicircular canals.

rinth are contained membranes having nearly the shape of the vestibule and semicircular canals, but not extending into the cochlea. These membranes, which compose what has been called the *membranous labyrinth*, form a continuous but close sac, containing a fluid, *endolymph*,—termed by M. De Blainville *vitrine auditive*, from its supposed analogy to the vitreous humour of the eye. It is similar in appearance to the perilymph which surrounds it on the outer side, and intervenes between it and the sides of the osseous labyrinth so as to prevent any contact. The form of

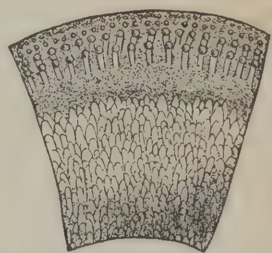
the membranous vestibule requires special notice, as it is not an exact imitation of the osseous cavity, being composed of two distinct sacs which open into each other; one of these is termed *utricle*, *sinus* seu *alveus utriculosus*, *sacculus vestibuli*, and *median sinus;* the other, *sacculus.* Each sac contains in its interior a small mass of white calcareous matter resembling powdered chalk, which seems to be suspended in the fluid of the sacs, by means of nervous filaments proceeding from the auditory nerves (Fig. 253). From the universal presence of these substances in the labyrinth of all the mammalia, and from their much greater size and hardness in aquatic animals, it is presumable, that they perform some office of importance in audition. They are termed by M. Breschet, *otolithes*, *otoliths;* and *otoconies*, *otoconia*, according as they are of a hard or a soft consistence.

Fig. 255.

Auditory Nerve taken out of the Cochlea.

1, 1, 1. Trunk of the nerve. 2, 2. Its filaments in the zona ossea of the lamina spiralis. 3, 3. Its anastomoses in the zona vesicularis.

Fig. 256.



Papillæ of the Auditory Nerve, on a segment of the Spiral Lamina of the Cochlea of a young Mouse.

The lower portion is the osseous, and the higher the membranous part of the lamina.—Magnified 300 times.

It is in the cavities of the internal ear, on different parts of the inner surface of the membranous labyrinth, and in the cochlea, that the *auditory* or *acoustic nerve* is distributed. This nerve is the *portio mollis* of the seventh pair, of most anatomists. It arises, like other nerves of the senses, from the medulla oblongata; and near the anterior paries of the fourth ventricle. Thence it passes obliquely outwards, forwards, and upwards, and enters the meatus auditorius internus, the foramen of which is situate on the posterior surface of the pars petrosa. The base of this meatus corresponds to the inner surface of the vestibule, and to the base of the cochlea. Through the first foramen, near the base of the meatus, the portio dura of the seventh pair or facial nerve passes to gain the aqueduct of Fallopius; along which it proceeds, giving off filaments to different parts of the middle ear, and ultimately issuing by the stylo-mastoid foramen to be lost on the muscles of the face. Below the part of the meatus, where the facial nerve emerges, are several other foramina, through which branches of the auditory nerve attain the labyrinth. These are distributed to the vestibule, ampullæ, and cochlea; and terminate, by very delicate ramifications, in the tissue and at the surface

of the membrane that lines the labyrinth. The precise mode in which the ramifications terminate has been a matter of dispute: some affirming, that they end in papillæ, as in the marginal figure from Treviranus (Fig. 256); others, that the fibres return by loops, which is not so probable. The arrangement is probably analogous to that which prevails in the retina.[1] Cells of vesicular matter were found not only in the terminal portion, but also in its trunk in many animals, by Dr. Brown-Séquard,[2] as well as by Corti and Kölliker.

Such is the apparatus concerned in the function of audition. Before proceeding to the physiology of these different parts, and the assistance afforded to the mind by this sense, it is necessary to enter into a brief physical disquisition on sound.

2. SOUND.

If a body, by percussion or otherwise, be thrown into vibration, every vibration excites a corresponding wave in the air; and these oscillations are propagated in all directions, until gradually lost in distance; but if they strike on the organ of hearing with the necessary force, a sensation is produced, which is called *sound* or *noise*. The term, however, is frequently used to signify not only the sensation, but the affection of the air, or of the sonorous body by which the sensation is effected.

That bodies move or oscillate when they produce sound admits of easy detection. We can see it in drums, bells, musical strings, &c., whose vibrations are extensive; and can arrest them, and with them the sound, by putting the hand upon the body or muffling it. Whenever a sonorous body is struck, a change in the relative position of its molecules is produced. These, by virtue of their elasticity, tend to return to their former place. This is done by a series of oscillations, which are, at first, more extensive; but become gradually less, until they finally cease. The rapidity of these oscillations is greater in bodies that are hard and elastic; and hence it has been concluded, that these two qualities render a body sonorous. It is not, however, a matter of facility to say, what is the precise cause of the difference of sound in analogous bodies. It must be dependent upon intimate composition, but of what nature is not intelligible to us. It is not long since there were but one or two individuals in Great Britain, who were celebrated for the fabrication of the larger order of bells for churches, colleges, &c., and in certain countries the art is comparatively unknown. Resonance is entirely owing to the intimate composition of the body, and is beautifully and singularly exhibited in the Chinese gong, the sound of which continues to rise for some time after a succession of rapid and forcible blows has been inflicted.

But, in order that sonorous oscillations may affect the organ of sense, an intermediate body is necessary to repeat and transmit them. This body is called the *vehicle of sound*, and it is usually air. M. De Lamarck supposes the existence, in the atmosphere, of a vibrative fluid of great

[1] See, on the subject of the termination of the auditory nerve, Todd and Bowman, Physiological Anatomy and Physiology of Man, Amer. edit., p. 457, Philad.; and Kölliker. Mikroskopische Anatomie, 2ter Bd. § 289, Leipzig. 1854; or Amer. edit. of the translation of his Human Histology, p. 774, Philad., 1854.

[2] Medical Examiner, August, 1852, p. 501, and August, 1853, p. 490.

subtilty, which pervades the globe as well as the bodies on its surface; and Geoffroy St. Hilaire affirms, that sound "is a matter resulting from the combination of the external air, with the polarized air of the sonorous body!"—but these are topics that belong to works on higher physics.

Air, by virtue of its elasticity, is admirably adapted as a vehicle for sound; and the loudness of the sound conveyed by it is greatly dependent upon its density. If we put a bell under the receiver of an air-pump, and exhaust the air, the sound becomes gradually more and more faint, and when the air is exhausted is not heard at all. For the same reason a pistol fired on the top of the Himalaya Mountains gives a much feebler report than in the valleys beneath.

Sympathetic sounds afford additional evidences of the carrying power of air. Every sonorous, elastic body can be thrown into oscillations, if the air surrounding it be made to tremble. Thus, if we sound a note near a piano-forte, whose dampers are raised so as to admit of free vibration, the string, that is in unison with the tone produced, will vibrate by *reciprocation;* and a wine-glass or goblet may, according to Dr. Arnott, be made to tremble, and even to fall from a table, by sounding on a violoncello near it the note that accords with its own. The strata of air, in proximity with the sonorous body, receive the first impulses; and from these they are successively propagated to others; much in the same manner as the undulations extend from the place in which a stone is cast on a surface of smooth water; except that the aerial undulations extend in every direction, whilst the aqueous proceed only horizontally. In this propagation from stratum to stratum a portion of the sound is necessarily lost; so that the loudest sound is heard only within certain limits; and, in all cases, its intensity is inversely as the square of the distance from the sonorous body.

By causing the sonorous undulations to proceed entirely in one direction, and preventing their escape in every other, sound may be rendered audible at a much greater distance. M. Biot found, that when he spoke in a whisper at one extremity of a cylinder upwards of one thousand yards long, he was distinctly heard at the other. In many large manufactories the knowledge of this fact is turned to good account. By having numerous tubes communicating with the different rooms of the establishment, and terminating in the office of the principal, he is enabled to have his directions readily conveyed, and to receive information without the slightest inconvenience. In a recent public Journal,[1] it is stated, that a gutta percha speaking tube, 400 feet long, and one inch in diameter, is used in a Liverpool printing office, and that messages are distinctly conveyed through it. This is said to be the greatest length of speaking tube ever used.

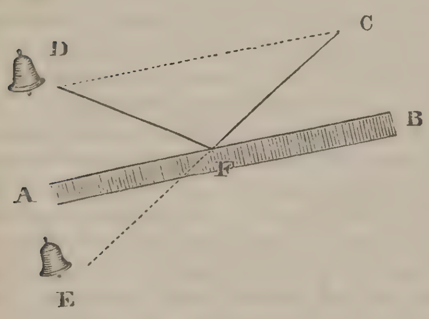
The velocity with which sound proceeds admits of easy calculation. Light passes with such rapidity, that it may be regarded as proceeding instantaneously from objects on the earth to the eye. The velocity of sound is incomparably less. We see the flash of a gun at a distance; and, some time afterwards, hear the report. Considering the light then to have reached the eye instantaneously, if we know the

[1] Illustrated London News, Dec. 1, 1855, p. 643.

distance of the gun, and note the time that elapsed between the appearance of the flash and the report, we can calculate accurately the rapidity of sound. This is found to be about eleven hundred and forty-two feet in a second. We can, in this manner, estimate the distance of a thunder-cloud, by noting the time of the flash, and the interval that elapses before hearing the clap. If it be thirty-seconds, the cloud is at a distance of thirty times eleven hundred and forty-two feet, or six miles and a half. The velocity is the same for all kinds of sounds. M. Biot found, on playing a flute at the end of the tube, above referred to, that the tones arrived at the ear placed at the other extremity in due succession; so that their velocity must have been uniform.

When aerial oscillations meet with a resisting body of a regular surface, as A B, Fig. 257, they are reflected at an angle equal to the angle of incidence: consequently, an ear, placed in the course of the reflected waves as at C, will refer the sound to a distance as far behind the point of reflection, and in the direction of the reflected ray, as the sonorous body is from the point of reflection. It will seem to be at E. The ear at C will, however, receive the direct oscillations from the bell D, as well as those that proceed along the lines D F and F C; or in other words, it will hear both the sound and its echo; and, if the surfaces on which the sonorous undulations impinge be favourably disposed, the echoes may be very numerous. The utility of the *ear trumpet*, and *speaking trumpet*, is to be explained by this law of the reflection of the aerial undulations; and some physiologists are of opinion, that the external ear is inservient to audition on similar principles. The *ear trumpet* is a tube, narrow at one extremity, so as to enter the concha; and expanded at the other like a trumpet. It is also curved, so that it may be easily directed to objects. All the sonorous rays, that enter the expanded extremity, are brought after various reflections to a focus in the auricular end; and the intensity of the sound is, in this way, so much augmented, that a person who, without it, is entirely deaf to common conversation, may enjoy it. A sheet of paper, folded like a cone, the apex of which is placed in the concha, and, to a less extent, the hand held concavely behind the ear, serve a like purpose.

Fig. 257.



Reflection of Sound.

Air is not the only, nor the most perfect, vehicle of sound. The personal experiments of divers show, that it can be conveyed through water. The blows of workmen around a diving bell are distinctly heard above; and fish have manifestly an acute sense of hearing, although this was at one time denied. An experiment, made by the

Abbé Nollet, and repeated by Dr. Franklin, proves, that water transmits a much stronger vibration than air. When two stones were struck together under water, a shock was given to the immersed ear, which was almost insupportable. The latter philosopher found by experiment, that sound, after travelling above a mile through water, loses but little of its intensity. According to Chladni, its rate of progression in water is about 4900 feet in a second, or between four and five times as great as in air. Solids, too, are much better conductors of sound than air. If we scratch one end of a wooden rod, the sound is distinctly heard by the ear applied to the other; although it may be inaudible through the air. Savage tribes are in the habit of discovering the advance of enemies, or of their prey, by applying the ear to the ground; and watchmen, in some towns, instead of springing a rattle, and alarming offenders, strike the pavement with a staff, the sound of which is heard by their fellow-watchmen at a considerable distance. It is a common practice to ascertain, whether a kettle boils, by putting one end of a poker on the lid, and the other to the ear. The difference between simmering and boiling is in this way detected. A knowledge of the ready communication of sound through solids, has given rise to a valuable suggestion for the discrimination of diseases of the chest, and of various healthy and morbid conditions. By putting the ear to the chest we can hear the rush of air along the bronchial tubes, the pulsations of the heart, &c., and can discover any aberration in the execution of their functions. This is what was called by the late distinguished Laënnec, of Paris—the proposer of the method—*immediate auscultation.* The direct application of the ear to the chest is, however, frequently inadmissible. In these cases he used a hollow cylinder called a *stethoscope*, one end of which he applied to the chest—the other to the ear. This plan he termed *mediate auscultation.* The suggestion has led to valuable improvements in diagnosis.

MM. Hassenfratz and Biot have made some accurate experiments on the comparative rapidity of the progress of sound through air and solid bodies. The latter found, in the aqueducts of Paris, that a blow, struck upon a pipe nine hundred and fifty-one metres, or about ten hundred and forty yards, in length, was heard two seconds and a half sooner through the sides of the pipe than through the air within; but the sound did not extend so far. Ice conveys sound even better than water; for if a cannon be fired from a distant post—a frozen river intervening—each flash is followed by two distinct reports, the first conveyed by the ice,—the second by the air.

It has been already stated, that the vibrations of air, caused by a sonorous body, are capable of exciting corresponding or *sympathetic vibrations* in solid bodies within their sphere of action. It was an old observation, that such vibrations are excited only in bodies that are in unison with the sonorous body; in other words, in those that are capable of producing the same tone. Unison, however, is not necessary. When a sound is produced in air, every body receives a vibration, which is a repetition of the one that occasioned the sound. This M. Savart proved by using small membranes on which he placed fine sand. They were agitated; and the sand assumed various regular arrangements, whenever a sound was produced in their vicinity. In

other words, the membrane was thrown into vibration, not as a whole, unless its fundamental note was in unison with the one sounded; but in distinct segments, every one of which reciprocated the sound. This law of physics is important in its physiological relations. The apparatus of audition consists of several membranous structures, which are thrown into oscillation, whenever the ear receives the impressions of sound.

Professor Müller has inferred, from an extensive investigation of acoustic principles, applicable to the subject under consideration, that sonorous vibrations produced in water are communicated with considerable intensity to solid bodies; that vibrations of solid bodies are communicated with greater intensity to other solid bodies than to water; but with much greater intensity to water than to air,—that they are communicated from air to water with great difficulty; but the communication is much facilitated by the intervention of a membrane extended between them,—that vibrations passing from water to solid bodies are returned with increased intensity to the water; so that sound is heard loudly in the vicinity of those bodies, when if it originated in the conducting power of the water alone it would be faint,—that thin membranes conduct sound in water without any loss of its intensity, whether they are tense or loose;—that when vibrations are communicated from water to air inclosed in membranes or solid bodies, a considerable increase in the intensity of the sound is produced by the resonance of the circumscribed air;—that air inclosed in a membrane, surrounded by water, increases the intensity of the sound by resonance, when the sonorous vibrations are communicated to it by a solid body; —that vibrations, in passing from air directly into water, are considerably diminished in strength; but if a tense membrane exists between the air and the water the vibrations are communicated from the former to the latter with great intensity;—that the vibrations are communicated, without any perceptible diminution, from the air to the water, when to the membrane forming the medium of communication a short solid body is attached, which occupies the greater part of its surface, and is alone in contact with the water; and lastly, that a small solid body, fixed in an opening by means of a border of membrane so as to be movable, communicates sonorous vibrations, from air on one side to water on the other, much better than solid media not so constructed; but the propagation of sound to the fluid is rendered much more perfect if the solid conductor, thus occupying the opening, is, by its other end, fixed to the middle of the tense membrane, which has air on both sides.[1]

The bearing of these facts on the physiology of audition will presently be apparent.

The vibrations, which produce sound, differ much as regards their extent and rapidity; and on these differences two of the qualities of sound—*strength* and *tone*—are dependent. *Strength* or *intensity* depends on the extent of the vibrations of a sonorous body. This is seen in a musical string, the sound of which becomes weaker as the extent of the oscillations diminishes. The *tone*, on the other hand, is dependent on

[1] J. Müller, Elements of Physiology. By William Baly, M. D., ii. 1215. Lond., 1839.

the rapidity of the oscillations;—on their number in a given time. The tone, produced by a string or other sonorous body that vibrates quickly, is termed *acute* or *sharp*, when compared with that of one which vibrates more slowly. The latter is called *grave*, when compared with the former. The gravest sound that the ear can appreciate is considered to result from thirty-two vibrations per second; the most acute, from eight thousand one hundred and ninety-two vibrations, according to some;—twelve thousand, according to others. Some well-devised experiments, however, made by M. Savart, largely extend these limits, and appear to indicate that they cannot be esteemed rigidly fixed. In his experiments, the ear distinctly appreciated fourteen or sixteen vibrations, or seven or eight impulses per second; and the acutest note that was audible proceeded from upwards of forty thousand vibrations, or more than twenty thousand impulses per second. M. Despretz[1] has determined, that classifiable sounds are comprised between the limits of 32 simple vibrations for the lowest tone, and 73,000 for the highest.

The duration of the impression of a sonorous vibration on the ear has been estimated at about the sixteenth part of a second; but it is difficult to determine it exactly.

If a sonorous body be struck, and the vibrations excited be all performed in equal times, a simple and uniform sensation is produced on the auditory nerve, and one *musical tone* is heard. But if the vibrations be various and irregular, they fall scatteringly on the organ of hearing, and excite a harsh impression, as if various sounds were heard together. In other words a *noise* or *discord* is produced. If two notes, sounded together, afford pleasure. they produce *harmony* or *concord*. This arises from the agreement of the vibrations, so that some of them strike upon the ear at the same time. If, for example, the vibrations of one sonorous body takes place in double the time of another, the second vibration of the latter will strike upon the ear at the same instant as the first vibration of the former. This is the concord or harmony of an *octave*. Between a note and its octave, there are six intermediate notes, constituting the *diatonic scale* or *gamut*. If the vibrations of two strings are as two to three, the second vibration of the former will correspond with the third vibration of the latter, producing the harmony called *a fifth*. There are other tones, which, although they cannot be struck together without producing discord, if produced in succession, give the pleasure called *melody*. Melody is, in truth, nothing more than the effect produced on the brain by pleasing musical tones sounded in succession.

There is another quality of sound which the French call *timbre*. By some of the translators of the works of the French physiologists and physicists this word has been rendered *note*. It is essentially different from note or tone; and is peculiar. By English philosophers it is termed *quality* of sound. It is this *quality* that enables us to recognize various instruments, when giving forth the same note or tone; and to distinguish the voices of individuals from each other. Its cause is not

[1] Comptes Rendus, xx. 1214, cited by Longet, Traité de Physiologie, ii. 136, Paris, 1850.

evident, but is conceived to depend upon the nature of the sonorous body, if it be a surface,—and at the same time on its shape, if a tube. M. Biot conjectures, that it is owing to the series of harmonic sounds that form part of every appreciable sound. When any sonorous body is made to vibrate, a distinct sound is heard, which is the *fundamental;* but, if attention be paid, others are heard at the same time. These are called *harmonics;* and it is not improbable that *timbre* or *quality* may be dependent as well upon the nature of the sonorous body, as upon the greater or less number of harmonics, that accompany the fundamental sound.[1]

3. PHYSIOLOGY OF AUDITION.

In tracing the progress of sonorous vibrations to the internal ear, we shall follow the order of parts described in the anatomical sketch of the auditory apparatus;—commencing with the *external ear.* The meatus auditorius externus being always open, sonorous vibrations can readily reach the membrana tympani. Some of these pass directly to the membrane without experiencing reflection, and communicate their oscillations to it. The *pavilion* has been regarded, by most physiologists, as a kind of ear-trumpet, for collecting aerial undulations, and directing them, after various reflections, to the bottom of the auditory canal. In the horse, and in those animals which have the power of pricking the ears, or of moving them in various directions, this is doubtless the case; but in man we cannot expect any great effect of the kind, if we regard its arrangement, and the incapability of moving it from its fixed direction, which is nearly parallel to the head. Boerhaave,[2] indeed, pretended to have proved by calculation, that every sonorous ray, which falls upon the pavilion, is ultimately directed towards the meatus auditorius externus. Simple inspection of the pavilion shows that this cannot be universally true. Some part of the anthelix is, in almost every individual, more prominent than the helix; and it is therefore impossible for the undulations, that fall upon the posterior surface of the former, to be reflected towards the concha. M. Itard,[3] a distinguished physiologist and aurist of Paris, asserts, that he has never seen the loss of the pavilion affect the hearing; and many animals, whose sense of hearing is acute,—the mole and birds, for example,—are devoid of it. Hence he concludes, that it is, perhaps, rather injurious than favourable to audition; and is more inservient to the expression than to the hearing of the animal.

M. Itard's view is doubtless too exclusive. The pavilion may have but little agency as an ear-trumpet, but it must have some. The concha, being the expanded extremity of the meatus auditorius, must receive more sonorous vibrations than could be admitted by the meatus itself. These are reflected towards the membrana tympani, and reach it in a state of concentration—but, to no great amount, it is true. In this way, and perhaps in that suggested by M. Savart,[4] the pavilion is

[1] On sonorous undulations in general, see Müller, loc. cit.
[2] Prælect., tom. iv. p. 317.
[3] Traité des Maladies de l'Oreille et de l'Audition, i. 131, Paris, 1821.
[4] Annales de Chimie, xxvi. 5; and Journal de Physiologie, iv. 183, and v. 367.

useful in audition. That gentleman is of opinion, that the whole of the external ear, the elasticity of which he considers to be capable of slight modification by the action of its proper muscles, is an apparatus for *repeating* sonorous vibrations, and transmitting or conducting them along its own parietes to the membrane of the tympanum. According to this view, the different inequalities of surface of the pavilion admit of explanation. When the membrane is stretched in a direction parallel to a sonorous surface, the oscillations, impressed upon it, are most marked; and, accordingly, as sounds impinge upon the pavilion from various quarters, the inequalities of surface always admit of some being disposed in the most favourable way for the reception of vibrations. It is true that the pavilion is not essential to audition,—the hearing not suffering by its removal for more than a few days; so that its physiological influence is much more limited than might be conceived. It probably contributes to a knowledge of the direction of sounds, and is certainly calculated to protect the membrana tympani.

The *meatus auditorius externus* conducts the sonorous vibrations directly, and by reflection, as well as by its parietes, to the membrana tympani. It is probable, too, that it is useful in protecting the membrane from the direct action of air and extraneous bodies. This is, perhaps, the cause of its tortuous character. If too much so, hearing becomes impaired,—the sonorous oscillations not being properly directed towards the membrane. Baron Larrey has published cases of deafness produced in this manner, which were removed by wearing an artificial concha and meatus of the natural curvature made of gum elastic. The down or hairs, at the entrance of the meatus, have been regarded as protecting agents against the intrusion of extraneous bodies; whilst the cerumen has been looked upon as a fit material for entrapping insects in the slough formed by it, or for destroying them by its poisonous influence. It is probable, however, that the most important function of the cerumen is to keep the lining membrane of the meatus in a physical condition adapted for the proper fulfilment of its functions.

Middle Ear.—In the mode described, the vibrations of a sonorous body attain the membrana tympani. An experiment by M. Savart would seem to show, that the membrane is thrown into vibrations chiefly by the air contained in the meatus. He made a small truncated cone of pasteboard, and closed the narrow extremity by a tense membrane, nearly as the membrana tympani closes the inner extremity of the meatus auditorius; and he found, that when sounds were produced near the parietes of the cone, the membrane vibrated but little; whilst if they were occasioned opposite the base of the cone, so that they could be transmitted to the membrane by the air within the canal, the vibrations were distinct, even at a distance of thirty yards and upwards.

The membrane of the tympanum, then, receives and repeats the sonorous vibrations. It has, however, been supposed to be possessed of other functions. M. Dumas[1] conceived it to be composed of numerous cords, each corresponding to some particular tone. But of this

[1] Principes de Physiologie, 2de édit., Paris, 1806.

arrangement we have no evidence from observation or analogy. By others, it has been supposed, and with probability, that the membrane is capable of being rendered tense, or the contrary, by the bent lever formed by the chain of ossicles. They have farther presumed, that this tension or relaxation is adapted to the sounds, which the membrane has to transmit. The ancients believed, that the adaptation was produced by the stretching of the membrane, so as to put it in unison with the sound produced. Independently, however, of the experiments of M. Savart, which show, that unison is not necessary for the production of vibrations, the fact, that we are capable of distinguishing several sounds at the same time, would seem to negative the supposition. Nor can we easily conceive, that the membrane could admit of as many distinct vibrations as the ear is capable of accurately appreciating tones, amounting to about eight octaves. Bichat thought, that the degree of tension of the membrane corresponded with the intensity of sounds; and that by it the sonorous vibrations attained the internal ear in a degree sufficiently strong to excite the appropriate impression, but not so strong as to cause pain,—the membrane becoming more tense for a feeble sound, and relaxed for one too strong. In support of this view, Bichat cites the case of several persons, who could not hear ordinary sounds, until the ear had been impressed by louder, which, according to him, roused the membrane to tension. M. Savart, on the other hand, from the fact that every membrane vibrates with more difficulty, and less extensively, according to its tension, conjectures that the membrane is relaxed in the case of very feeble or agreeable sounds, and is rendered tense to transmit the too powerful or disagreeable.

Again, it has been conceived that the tension varies with the tone of the sound,—being augmented, according to some physiologists, in acute, according to others, in grave sounds. Sir Everard Home,[1] it has been remarked, esteems the membrane to be muscular; and he affirms, that it is chiefly by means of this muscle, that accurate perceptions of sound are made by the internal organ; and that the membrane can alter its degree of tension. It has been before observed, that the muscles, attached to the small bones, are capable of varying this tension; that the internal muscle of the malleus or tensor tympani, for example, by its contraction, renders it more tense.[2] Sir Everard admits, "that the membrana tympani is relaxed by the muscle of the malleus, but not for the purpose alleged in the commonly received theory. It is stretched in order to bring the radiated muscle of the membrane itself into a state capable of acting, and of giving those different degrees of tension to the membrane, which empower it to correspond with the variety of external tremors: when the membrane is relaxed, the radiated muscle cannot act with any effect, and external tremors make less accurate impressions." The reader is referred to the remarks already made on the views of Sir Everard in their anatomical relations. His speculations do not, however, end here. He employs

[1] Lect. on Comp. Anat., iii. 265.

[2] See on the Functions of the Muscles of the tympanum in the human ear, Mr. Toynbee, Brit. and For. Med.-Chir. Rev., Jan., 1853, p. 235.

the discovery to account for the difference between a "musical ear," as it is usually termed, and one which is incapable of discriminating, or feeling pleasure from, the succession of musical tones,—with what success we shall inquire presently. The truth is, that none of the conjectures, which have been proposed regarding the precise effects of tension or relaxation of this membrane, can be looked upon in any other light than as ingenious speculations, based, generally, upon the fact, that the membrane seems certainly capable of being varied in its tension by the movements of the chain of bones, but leading to no certain knowledge of the precise effect on audition of such tension or relaxation.[1] In fact, although the integrity of the membrane is necessary for perfect hearing, its perforation or destruction does not induce deafness. We have numerous cases of perforation from accident and otherwise, related by Messrs. Valsalva,[2] Willis,[3] Riolan,[4] Flourens, and others, in which the hearing continued; and, in certain cases of deafness, the membrane is actually punctured for the purpose of restoring the hearing.

The communication of sonorous oscillations from the membrana tympani across the cavity of the tympanum to the internal ear is effected in three ways: 1st, by the air contained in the cavity of the tympanum; 2dly, by the chain of bones to the membrane of the foramen ovale; and 3dly, by the parietes of the tympanum. So that, if the membrana tympani should be punctured or destroyed, the aerial undulations, caused by a sonorous body, which enter the meatus auditorius, may extend into the cavity of the tympanum, and excite corresponding oscillations in the membranes of the foramen ovale, and foramen rotundum. The chorda tympani, composed, perhaps wholly, of a branch of the fifth pair,—but on this anatomists are by no means agreed—and distributed on the interior of the membrana tympani, probably conveys no acoustic impression to the brain. To it is owing the excessive pain, which is caused by the contact of an extraneous body with the membrane; and that occasioned by a loud noise, or by compressing the air forcibly in the meatus by passing the finger suddenly and strongly into the concha.

The uses of the *mastoid cells*, which communicate with the middle ear, are not known. It would seem, that the strength of audition is in a ratio with their extent. In no animals are they more ample than in birds, which are possessed of great delicacy of hearing. This effect may be induced either by their enlarging the cavity of the tympanum, and allowing the sonorous oscillations to come in contact with a larger surface; or by the plates which compose them being thrown into vibration. It has been conceived, too, that they may serve as a diverticulum for the air in the middle ear, when it is subjected by the membrana tympani to unusual compression.

Sir Charles Bell,[5] with more warmth than is judicious or courteous,

[1] For the fancied uses of this membrane, see Haller, Element. Physiol., v. 198, Lausan., 1769, and on the functions of the muscles of the tympanum in the human ear, Toynbee, loc. cit.

[2] Op. Anat. de Aure Humanâ, &c., Ed. J. A. Morgagni, Venet., 1740.

[3] Oper. Omn. Venet., 1720.

[4] Enchirid. Anat., l. iv. c. 4, Lugd. Bat., 1649.

[5] Op. citat., i. 269.

combats the idea of the *foramen rotundum* receiving the undulations of air. The oblique position of the membrane of the foramen with regard to the membrana tympani satisfactorily, he thinks, opposes this doctrine. The function which, with M. Savart, he assigns to it—if not accurately, at least ingeniously—is the following. As the membrane of the foramen ovale receives the vibrations from the chain of ossicles, these vibrations circulate through the intricate windings of the labyrinth, and are again transmitted to the air in the tympanum by the foramen rotundum. The different cavities of the labyrinth being filled with incompressible fluid, no such circulation, he insists, would occur, provided the parts were entirely osseous. As it is, the membrane of the foramen rotundum gives way, "and this leads the course of the undulations of the fluid in the labyrinth in a certain unchangeable direction." The explanation of Sir C. Bell is not as convincing to us as it seems to be to himself. The membrane of the foramen rotundum does not appear to be required for the undulation in the cavities of the labyrinth, which he describes; as the liquor of Cotunnius can readily reflow into the aqueducts of the vestibule and cochlea. The principal use of these canals would seem, indeed, to be, to form *diverticula* for the liquor when it receives the aerial impulses. Sir C. Bell cites the case—often quoted from Riolan—of an individual who was deaf from birth, and was restored to hearing by accidentally rupturing the membrana tympani, and breaking the ossicles with an ear-pick:—"*disrupit tympanum, fregitque ossicula, et audivit.*" In these and other cases, in which the membrana tympani and ossicles have been destroyed, and the hearing has persisted, the vibrations must have been conveyed to the parietes of the internal ear through the air in the cavity of the tympanum; and, notwithstanding the charge of "absolute confusion of ideas," brought against such individuals as Scarpa,[1] Magendie, Adelon, and others, who believe that the foramen rotundum receives the undulations of air, we must confess, that the idea of the communication of vibrations through that medium, as well as through the membrane of the foramen ovale, and the osseous parietes of the labyrinth, appears to us most solid and satisfactory.

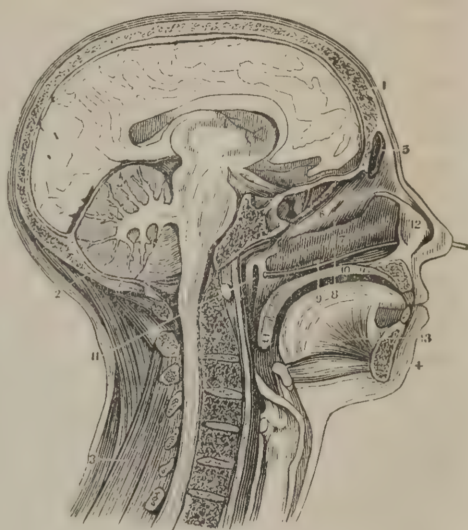
The *ossicles* or *small bones* have given occasion to the wildest speculations. At the present day, they are considered to fulfil one of two functions;—to conduct the vibrations from the membrana tympani,—or to stretch the membranes to which the extremities of the chain are attached. Both these offices are probably executed by them; the malleus receiving the vibrations from the membrana tympani, and conveying them to the incus,—the incus to the os orbiculare,—the os orbiculare to the stapes, and the stapes to the membrane of the foramen ovale, by which they are transmitted to the liquor of Cotunnius. M. Savart conceives, that the chain of ossicles is to the ear what the bridge is to the violin. It has been already observed, that the ossicles are not essential to hearing, although they may be required to perfect it; and that they may be destroyed without deafness being produced, provided the membrane of the foramen ovale remains entire, and the parts within the labyrinth retain their integrity. If, in the removal

[1] Anat. Disquis. de Auditu et olfactu, Ticin, 1789; and De Structurâ Fenestræ Rotundæ Auris, &c., Mutin, 1772.

of the stapes by ulceration or otherwise, the membrane of the foramen should be ruptured, the liquor of Cotunnius would of course escape, and partial or total deafness result. In some experiments instituted by M. Flourens on pigeons, he found, that the removal of the malleus and incus did not have much effect upon the hearing; but when the stapes was taken away it was greatly impaired, and still more so when the membranes of the fenestra ovalis and fenestra rotunda were destroyed.

The *Eustachian tube* is an important part of the auditory apparatus, and an invariable accompaniment of the membrana tympani in animals. Without the tube, the membrane would be almost devoid of function. Pathology shows us, in the clearest manner, that its integrity is necessary to audition; and that deafness is the consequence of its closure. Dr. Bostock[1] thinks, "it is perhaps not very easy to ascertain in what mode it acts, but it may be concluded that the proper vibration of the membrana tympani is, in some way, connected with the state of the air in the tube." The name of the cavity to which the tube forms a communication with the external air suggests an easy and sufficient explanation of its use. The *drum* of the ear, like every drum, requires an aperture in some part of its parietes, in order that its membranes may vibrate freely. The Eustachian tube serves this purpose, and its closure produces the same effect upon the membrana tympani at one end of the cylinder, and on the membrane of the foramen ovale at the other, as would be produced on the parchments of the ordinary drum by the closure of its lateral aperture.[2] We can, in this way, account for the temporary deafness, which accompanies severe cases of inflammation of the throat:—the swelling obstructs the Eustachian tube. Dr. Carpenter,[3] however, thinks that

Fig. 258.



Vertical Section of the Head and Neck through the Mesial Line, to show the opening of the Eustachian Tube and its relations to the Pharynx.

1. Section of the os frontis. 2. Section of the os occipitis. 3. Muscles on the back of the neck. 4. Integuments on the chin. 5. Frontal sinus. 6. Middle spongy bone. 7. Inferior spongy bone. 8. Middle meatus of the nose. 9. Inferior meatus of the nose. 10. Thickness of the roof of the mouth and floor of the nostril. 11. Opening of the Eustachian tube. A catheter is introduced in the nostril and about to enter the tube. 12. Cartilaginous nasal septum. 13. Genio-glossus muscle. 14. Soft palate.

[1] Physiology, 3d edit., p. 721, London, 1836.

[2] Henle, in Béraud, Manuel de Physiologie de l'Homme, p. 566, Paris, 1853.

[3] Human Physiology, § 357, London, 1842. See also Amer. edit., p. 696. Philad., 1855.

the effect of the hole in the side of a drum seems rather to be the communication of the sonorous vibrations of the contained air to the ear of the observer, which are thus transmitted directly through the atmosphere, instead of being weakened by transmission through the walls of the instrument; and hence he concludes, that there is no real analogy between the two cases.

During the constant efforts of deglutition the air is renewed in the cavity of the tympanum; and, as the extremities of the Eustachian tube terminate in the pharynx, it enters at a modified temperature. The writer, last cited, thinks the principal object of the tube seems to be maintenance of the equilibrium between the air within the tympanum and that without, so as to prevent the inordinate tension of the membrane, that would be produced by too great or too little pressure on either side; the effect of which would be impaired hearing.

By closing the nose and mouth, and forcing air from the lungs, we can feel a sensation of fulness in the ear, produced by the pressure of the air against the internal surface of the membrana tympani; and they, who have the membrane perforated, can send tobacco smoke copiously out of the external ear.

Besides this necessary function, the Eustachian tube has been supposed to possess another,—that of serving as a second meatus auditorius, by permitting sonorous vibrations to enter the pharyngeal extremity, and, in this way, attain the middle ear. A simple experiment, first described by M. Pérolle,[1] exhibits the fallacy of this notion. If we carry a watch far back into the mouth, taking care not to touch the teeth, little or no sound will be heard; but if we draw the watch forward, so as to touch the teeth, the ticking becomes distinctly audible. If the pharyngeal extremity acted as a second meatus, the sound ought to be heard better when the watch is placed nearer to it; but such is not the case. On the contrary, it is not until the sonorous body is put in contact with the teeth, that the sound is appreciated. This is effected by the vibrations of the watch being conveyed along the bony parietes until they reach the auditory nerve. Again; if the meatus auditorius externus be completely closed, we cannot hear the voice of one who speaks into our mouth; and can hear but imperfectly our own. The fact of our gaping, when desirous of hearing accurately, has partly led to the belief, that the tube acts as a second meatus. It has been properly remarked, however, that this may be merely an act of expression; and, also, that the meatus auditorius is rendered more open, when we depress the lower jaw, than when it is raised, as may be perceived by inserting the little finger into the meatus, when the jaw is in the two situations.

In addition to these functions, it is probable, that the tube acts as a diverticulum for the air in the cavity of the tympanum, when the membrane is agitated by too powerful sounds. The closure of the tube is the cause of that form of deafness, which is relieved by injection of air or other fluids into it—a fact, the knowledge of which has been the foundation of much empiricism. It likewise conveys into the pharynx

[1] Hist. et Mém. de la Société Royale de Médecine, tom. iii.

the mucus secreted by the lining membrane of the tympanum, probably by means of the vibratile cilia on its mucous surface.

Internal Ear.—In the various ways mentioned, the vibrations of a sonorous body reach the internal ear. The membranes of the foramen ovale and foramen rotundum resemble the membrana tympani in their physical characteristics; and when thrown into vibrations communicate the impression to the liquor of Cotunnius contained in the cavities of the internal ear. By this medium, the vibrations are conducted to the auditory nerve, which conveys the impression to the brain.

Almost all the views entertained regarding the sympathetic vibrations of the membrana tympani have been applied to the membrane of the foramen ovale; our knowledge, however, is restricted to the fact, that its tension can be varied by the chain of ossicles, without our being able to specify the circumstances under which this takes place. M. Adelon asserts, that the membrane may be torn, and yet the sense of hearing not be destroyed. This seems scarcely possible, as the liquor of Cotunnius must necessarily escape, and so much morbid action be induced as to render audition impracticable.

The membrane of the foramen rotundum, which forms the medium of communication between the cavity of the tympanum and the cochlea, has no chain of bones to modify its tension. The vibrations into which it is thrown, as well as those of the vestibular membrane, are imparted, as we have seen, to the liquor of Cotunnius, which is present in every ear, and appears essential to audition.

Of the precise use of the *vestibule*, *semicircular canals*, and *cochlea*, we have very limited notions. The beauty and complexity of their arrangement has given rise to various conjectures. M. Le Cat[1] considered the lamina spiralis to consist of numerous minute cords, stretched along it, and capable of responding to every tone. M. Magendie[2] affirms, that no one admits this hypothesis regarding the use of this osseo-membranous septum; but he is in error. Sir C. Bell[3] asserts, that the cochlea is the most important part of the organ of hearing; or rather, that it is "the refined and higher part of the apparatus;" and he considers the lamina spiralis as the only part adapted to the curious and admirable powers of the human ear for the enjoyment of melody and harmony. The subject of the musical ear will engage us presently. It may be sufficient to remark, that there is no ratio in animals, between their delicacy of hearing and the degree of complication of the cochlea. The cochlea of the Guinea pig is more convoluted than that of man; yet we can hardly conceive it to have a better appreciation of musical tones; whilst in birds, whose hearing is delicate, the organ is, as we have remarked, simple, and has no spiral arrangement.

Again; the semicircular canals have been compared to organ pipes, adapted for producing numerous tones; and Dr. Young[4] supposes them to be "very capable of assisting in the estimation of the acuteness or pitch of a sound, by receiving its impression at their opposite ends;

[1] Traité des Sens, Paris, 1767, or English translation, London, 1750.
[2] Précis, &c., i. 121. [3] Op. citat., ii. 273.
[4] Med. Literature, p. 98, London, 1813.

and occasioning a recurrence of similar effects at different points of their length according to the different character of the sound; while the greater or less pressure of the stapes must serve to moderate the tension of the fluid within the vestibule, which serves to convey the impression." "The cochlea," he adds, "seems to be pretty evidently a micrometer of sound." Professor Samuel Jackson[1] is of opinion, that they serve to suppress the sonorous vibrations of the lymph of the vestibule. They arrest—he says—the waves of reflection, which would necessarily occur in a simple cavity wholly limited by a plane surface, as the vestibule would be without these appendages. The consequence of reflected undulating vibrations in the fluid of the labyrinth would be the production of mere sound or noise of different intensities. "The perception of the immense number of fine and delicate tones, and other qualities of sound of which the ear has cognizance, would be utterly impossible in the confusion of sonorous vibrations in the fluid of the labyrinth continuously reflected to and fro, unless some provision is made for their suppression. The molecules of a fluid contained in a close vessel continue in undulatory vibration until the impetus exciting their motion is expended or suppressed." The semicircular canals, according to him, accomplish this purpose. They are, in the apparatus of hearing, what the pigmentum nigrum of the choroid coat is in that of vision.

Another view—to be remarked upon hereafter—is, that their peculiar function is the reception of the impressions by which we distinguish the direction of sounds. All these are mere hypotheses; ingenious, it is true, but still hypotheses; and, in candour, it must be admitted, that we have no positive knowledge of the precise functions of either vestibule, cochlea, or semicircular canals. Our acquaintance with the first two is limited to this;—that they contain the final expansions of the auditory nerve; and that it is within them, that the nerve receives its impressions from the oscillations of sonorous bodies.

It has been observed, that sonorous vibrations may reach the nerve by the bony parietes, and that the ticking of a watch held between the teeth is, in this way, heard. A blow upon the head is distinctly audible; and Ingrassias[2] relates the case of a person, who had become deaf in consequence of obstruction of the meatus auditorius externus, and yet could hear the sound of a guitar by placing the handle between his teeth, or by making a communication between his teeth and the instrument by means of a metallic or other rod. The physician has recourse to a plan of this kind for detecting if a case of deafness be dependent upon obstructed Eustachian tube; upon some affection of the meatus auditorius externus; or upon insensibility of the auditory nerve, or of the part of the brain where the sensation is accomplished. If the latter be the fact, the ticking of a watch, applied to the teeth, will not be audible, and the case will necessarily be of a hopeless character. If, on the other hand, the sound be perceived, the attention of the physician may be directed, with well-founded expectation of suc-

[1] Unpublished Lecture, in a Note to Amer. edit. of Carpenter's Principles of Human Physiology, p. 699, Philad., 1855.

[2] De Ossibus, p. 7. Also, Boerhaave, Prælectiones, iv. 415, and Haller, Element. Physiol., tom. v. p. 253, Lausann., 1763.

cess, to the physical parts of the organ, or to those concerned in the transmission of vibrations. Frequently, it will happen, in such cases, that the Eustachian tube is impervious, when properly directed efforts may succeed in removing the obstruction; or, if this be impracticable, temporary, if not permanent, relief may be obtained by puncturing the membrana tympani, and allowing the aerial undulations, in this way, to reach the middle and internal ear.

Lastly;—as regards the precise *nerve of hearing*. In this sense, we have the distinction between the nerve of general, and that of special sensibility more clearly perceptible. The experiments of M. Magendie[1] have shown, that the portio mollis of the seventh pair is a nerve of special sensibility;—that it may be cut, pricked, or torn, without exhibiting any general sensibility, and is inservient to the sense of hearing only. The same experiments demonstrate, that it cannot act unless the fifth or nerve of general sensibility is in a state of integrity. If the latter be divided within the cranium, hearing is always enfeebled, and frequently destroyed. Dr. Brown-Séquard,[2] however, affirms, that the degree of pain produced by an excitation of the "nervous centre"—as he regards the auditory nerve—appears to be as considerable as that caused by a similar excitation of the nerve of the fifth pair.

The experiments of M. Flourens,[3] to which allusion has been made, led him to infer that the rupture of the cochlea was of less consequence than that of the semicircular canals. Laceration of the nerve, distributed to the vestibule, enfeebled the hearing, and its total destruction was followed by irreparable deafness. For these, and other reasons afforded by comparative anatomy, M. Lepelletier[4] infers, that, in the higher organisms, the vestibule and its nerve constitute the essential organ of impression; the other parts being superadded to perfect the apparatus.

An interesting case of malformation has been related by Professor Mussey,[5] of Cincinnati, which shows, that other nerves besides the portio mollis of the seventh pair may, under unusual circumstances, be inservient to audition. In this case there was no appearance of meatus auditorius externus in either ear, and yet the man, twenty-seven years of age, although his sense of hearing was too obtuse for low conversation, could hear sufficiently well to prosecute his business—that of a bookseller—without material inconvenience. By covering the head with layers of cloth, the hearing was manifestly obscured. On speaking to him with one end of a stick in the speaker's mouth, whilst the other end was applied in succession to different parts of the head and face, it was found, that the part over the mastoid process conducted sound most readily; and that the parts corresponding with the upper two-thirds of the occipital, the mastoid plate of the temporal, and the posterior half of the parietal bone, transmitted sounds more readily than the anterior half of the scalp, the forehead, temples, or any other part of the face. Professor Mussey infers, from the results of his observations on this case, that the nerves, derived from the spinal cord

[1] Précis, &c., 2de édit., i. 114. [2] Medical Examiner, Aug., 1853, p. 490.
[3] Expériences sur le Système Nerveux, p. 42, Paris, 1825, or 2de édit., Paris, 1842.
[4] Traité de Physiologie Médicale et Philosophique, iii. 143, Paris, 1832.
[5] American Journal of the Medical Sciences, Feb., 1838, p. 378.

below the foramen magnum of the occipital bone, and reflected in profusion over the scalp, were concerned in this unusual function, and that the branches of the fifth nerves were probably the seat of the peculiar faculty on the face.[1] A case also was communicated to the author by the Rev. Dr. Parker, of Macao, in which there was no evidence of external ear. The hearing was very indistinct. Under the idea, that the internal organs were perfect, and that, to render the hearing so, it was only necessary to perforate the integument so as to admit the air to the tympanum, Dr. Parker, at the request of the youth and his parents, determined to perforate one ear. In accordance with Chinese prejudice in favour of the cautery, caustic potassa was applied, and "as soon as the slough from the first applications was removed, the hearing was surprisingly improved." No cavity, however, could be discovered. After different operations, he was able to hear a whisper.[2]

The immediate function of the sense of hearing is to appreciate sound; and we may apply to it what has been said of the other senses; that, in this respect, it cannot be supplied by any other; is instinctive; requires no education; and is exerted as soon as the parts have attained a due degree of developement.

Amongst the advantages afforded by the possession of this sense, which has been well termed *intellectual*, are two of the highest gratifications we enjoy,—the appreciation of music, and the pleasures of conversation. To it we are indirectly indebted for the use of verbal language—the happiest of all inventions—as it has been properly termed; to which we shall have to advert hereafter.

Metaphysicians and physiologists have differed widely in their views regarding the organs more immediately concerned in the appreciations in question. Many, for example, have referred the faculty of music to the ear; and hence, in common language, we speak of an individual, who has a "*musical ear*," or the contrary. Others, more philosophically, have considered, that the faculty is encephalic; that the ear is merely the instrument for conveying the sonorous undulations, which, in due order, constitute melody; but that the appreciation is ultimately effected in the brain. "That it" (the power of distinguishing the musical relations of sounds), says Dr. Brown,[3] "depends chiefly, or perhaps entirely, on the structure or state of the mere corporeal organ of hearing, which is of a kind, it must be remembered, peculiarly complicated, and therefore susceptible of great original diversity in the parts, and relations of the parts that form it, is very probable; though the difference of the separate parts themselves, or of their relations to each other, may, to the mere eye, be so minute, as never to be discovered by dissection." Many physiologists of eminence have regarded the complex internal ear as the seat of the faculty; some looking to the cochlea; others to the semicircular canals; and but few referring it to the brain. Sir C. Bell, indeed, asserts, that "we are not perhaps warranted in concluding, that any one part of the organ of hearing

[1] A similar case by Mr. Swan is in Medico-Chirurgical Transactions, vol. xi.
[2] First Report of the Ophthalmic Hospital, Canton, Feb., 1826.
[3] Lectures on the Philosophy of the Human Mind, Edinb., 1820; or Amer. edit., vol. i. p. 207. Boston, 1826.

bestows the pleasures of melody and harmony, since the musical ear, though so termed, is rather a faculty depending on the mind." Yet afterwards he adds:—"We think that we find in the lamina spiralis (of the cochlea) the only part adapted to the curious and admirable powers of the human ear for the enjoyment of melody and harmony. It is in vain to say, that these capacities are in the mind and not in the outward organ. It is true, the capacity for enjoyment or genius for music is in the mind. All we contend for is, that those curious varieties of sound, which constitute the source of this enjoyment, are communicated through the ear, and that the ear has *mechanical* provisions for every change of sensation."[1] A cherished opinion of Sir Everard Home[2] on this subject has been given before. Conceiving the membrane of the tympanum to be muscular, he considers the membrana tympani, with its tensor and radiated muscles, to resemble a monochord, "of which the membrana tympani is the string; the tensor muscles the screw, giving the necessary tension to make the string perform its proper scale of vibrations; and the radiated muscle, acting upon the membrane, like the movable bridge of the monochord, adjusting it to the vibrations required to be produced;" and he adds: "the difference between a musical ear and one which is too imperfect to distinguish the different notes in music will appear to arise entirely from the greater or less nicety with which the muscle of the malleus renders the membrane capable of being truly adjusted. If the tension be perfect, all the variations produced by the action of the radiated muscle will be equally correct, and the ear truly musical." In this view,—as unsatisfactory in its basis as it is in some of the details,—Sir Everard completely excludes, from all participation in the function, the internal ear, to which the attention of physiologists, who consider the faculty to be seated in the ear, has been almost exclusively directed.

A single case, detailed by Sir Astley Cooper,[3] prostrates the whole of the ingenious fabric erected by Sir Everard. Allusion has already been made to the old established fact, that the membrane of the tympanum may be destroyed without loss of hearing necessarily following. Sir Astley was consulted by a gentleman, who had been attacked, at the age of ten years, with inflammation and suppuration in his left ear, which continued discharging matter for several weeks. In the space of about twelve months after the first attack, symptoms of a similar kind took place in the right ear, from which matter issued for a considerable time. The discharge, in each instance, was thin, and extremely offensive; and in it, bones or pieces of bones were observable. In consequence of these attacks he became deaf, and remained so for three months. The hearing then began to return; and in about ten months from the last attack, he was restored to the state he was in when the case was published. Having filled his mouth with air, he closed his nostrils and contracted the cheeks; the air, thus compressed, was heard to rush through the meatus auditorius with a whistling noise, and the hair, hanging from the temples, became agitated by the current of air that issued from the ear. When a candle was applied, the

[1] Anat. and Physiol., 5th Amer. edit., by Godman, ii. 273. New York, 1829.
[2] Lect. on Comp. Anat., iii. 268.
[3] Philosoph. Transact. for 1800, p. 151, and for 1801, p. 435.

flame was agitated in a similar manner. Sir Astley passed a probe into each ear, and thought the membrane of the left side was totally destroyed, as the probe struck against the petrous portion of the temporal bone. The space, usually occupied by the membrana tympani, was found to be an aperture without one trace of membrane remaining. On the right side, also, a probe could be passed into the cavity of the tympanum; but, on this side, some remains of the circumference of the membrane could be discovered, with a circular opening in the centre, about a quarter of an inch in diameter. Yet this gentleman was not only capable of hearing everything that was said in company, but was nicely susceptible to musical tones; "he played well on the flute, and had frequently borne a part in a concert; and he sang with much taste and perfectly in tune."

But, independently of these partial objections, the views which assign musical ear and acquired language to the auditory apparatus, appear liable to others that are insuperable. The man who is totally devoid of musical ear hears the sound distinctly. His sense of hearing may be as acute as that of the best musician. It is his appreciation that is defective. He hears the sound; but is incapable of communicating it to others. The organ of appreciation is—in this, as in every other sense—the brain. The physical part of the organ may modify the impression that has to be made upon the nerve of sense; the latter is compelled to transmit the impression as it receives it; and it is not until the brain has acted, that perception takes place, or that any idea of the physical cause of the impression is excited in the mind. If, from faulty organization, such idea be not formed in the case of musical tones, the individual is said not to possess a musical ear; but the fault lies in his cerebral conformation. We do not observe the slightest relation between musical talent and delicacy of hearing. The best musicians have not necessarily the most delicate sense; and, for the reasons already assigned, it will be manifest, why the idiot, whose hearing may be acute, is incapable of singing, as well as of speaking. Again, we do not see the least ratio in animals between the extent and character of their music and the condition of their auditory sense. We are compelled, then, to admit, that the faculties of music and speech are dependent upon organization of the brain; that they require the ear as an instrument; but that their degree of perfection is by no means in proportion to the delicacy of the sense of hearing. In these opinions, MM. Gall,[1] Broussais,[2] Adelon,[3] and other distinguished physiologists concur. "Speech," says M. Broussais, "is heard and repeated by all men, who are not deprived of the auditory sense; because they are all endowed with cerebral organization fit to procure for them distinct ideas on the subject. Music, when viewed as a mere noise, is also heard by every one; but it furnishes ideas, sufficiently clear to be reproduced, to those individuals only whose frames are organized in a manner adapted to this kind of sensation."

Yet, although we must regard the musical faculty to be intellectual,

[1] Sur les Fonctions du Cerveau, v. 96, Paris, 1825.

[2] Traité de Physiologie, translated by Drs. Bell and La Roche, p. 84, 3d Amer. edit., Philad., 1832.

[3] Op. citat., i. 383.

and consequently elevated in the scale, it is hardly necessary to say, that the want of it is no evidence of that mental and moral degradation, which has been depicted by poets and others.

> "The man that hath no music in himself,
> Nor is not moved with concord of sweet sounds,
> Is fit for treasons, stratagems, and spoils;
> The motions of his spirit are dull as night,
> And his affections dark as Erebus:
> Let no such man be trusted."
>
> SHAKSPEARE, "*Merchant of Venice*," v. i.

> "Is there a heart that music cannot melt?
> Alas! how is that rugged heart forlorn!
> Is there, who ne'er those mystic transports felt
> Of solitude and melancholy born!
> He needs not woo the muse; he is her scorn.
> The sophist's rope of cobweb he shall twine;
> Mope o'er the schoolman's peevish page; or mourn,
> And delve for life in mammon's dirty mine;
> Sneak with the scoundrel fox, or grunt with glutton swine."
>
> BEATTIE, "*Minstrel.*"

In the classification of the objects of human knowledge, music has been ranked with poetry; but we meet with striking evidences of their wide separation. Whilst the professed musician is frequently devoid of all poetical talent, many excellent poets have no musical ear. Neither does the power of discriminating musical tones indicate, that the possessor is favoured with the finer sensibilities of the mind; nor the want of it prove their deficiency. It has been a common remark, that amongst professed musicians, the intellectual manifestations have been singularly and generally feeble; a result partly occasioned by their attention having been almost entirely engrossed from childhood by their one favourite pursuit, but not perhaps to be wholly explained by this circumstance; and, whilst we find them often unmarked by any of the kindlier sympathies, we see those, that are "not moved with concord of sweet sounds," alike distinguished as philosophers and philanthropists.

The defect, in these cases, differs probably, in an essential manner, from one to which attention has been drawn by the late Dr. Wollaston,[1] who has detailed many curious facts, regarding what he terms a peculiarity in certain ears, which seem to have no defect in their general capacity for being impressed by sound, or in the perception of musical tones; but are insensible to very acute sounds. This insensibility commences when the vibrations have attained a certain degree of rapidity; beyond which all sounds are inaudible to ears thus constituted. Thus, according to Dr. Wollaston, certain persons cannot hear the chirp of the grasshopper; others, the cry of the bat; and he refers to one case, in which the note of the sparrow was inaudible. He himself was incapable of hearing any sound higher than six octaves above the middle E of the piano forte. The defect would, at first sight, appear to be referable to the physical part of the ear, rather than to the auditory nerve, or to the part of the brain concerned in the appreciation of sounds;—the vibrations that are performed with great rapidity not being responded to by the parts of the organ

[1] Philosophical Transactions for 1820, p. 306.

destined for that purpose; and, consequently, never reaching the auditory nerve. Researches, however, by M. Savart,[1]—a most dexterous and ingenious experimenter,—seem to show that the defect in the appreciation of acute sounds, in such cases, is not owing to their *acuteness* but to their *feebleness;* that if the sound can be made sufficiently intense, the ear is capable of hearing a note of upwards of forty thousand simple oscillations in a second; and that the cases referred to by Dr. Wollaston are, consequently, owing to defective hearing, rather than to insensibility to very acute sounds.

Another acquired perception of the ear is that of forming a judgment of the *distance* of bodies. This we do by attending to the loudness of the sound; for we instinctively believe, that a loud sound proceeds from a body near us, and a feeble sound from one more remote. This is the cause of numerous acoustic errors, in spite of all reason and experience. In the theatres, the deception is often admirably managed, when the object is to give the idea of bodies approaching. The sound —that of martial music, for example—is rendered faint and subdued; and, under such circumstances, appears to proceed from remote distance; and, by adding gradually and skilfully to its intensity, we are irresistibly led to the belief that the army is approaching; and the illusion is completed by the appearance of the military band on the stage, allowing its soul-inspiring strains to vibrate freely in the air. In like manner, we are deceived by the ventriloquist. He is aware of the law that guides us in our estimation of distance; and, by skilfully modifying the intensity of his voice, according as he wishes to make the sound appear to proceed from a near or a distant object, he irresistibly leads us into acoustic error.

Education or experience is required to enable us to appreciate distances accurately by this sense; as well as to judge of their position. In the case, detailed by M. Magendie,[2] of a boy, who, after having been entirely deaf until the age of nine, was restored to hearing by M. Deleau, by means of injections thrown into the cavity of the tympanum through the pharyngeal extremity of the Eustachian tube, one of the most remarkable points was his difficulty in acquiring a knowledge of the position of sonorous bodies. In forming an accurate judgment on this subject we seem to require the use of both ears. In all other cases an impression made upon one only would perhaps be sufficient. The common opinion is, that to judge of the direction of a sound we compare the intensity of the impression on each ear, and form our deductions accordingly; and that if we close one ear we are led into errors, which are speedily dissipated by employing both. Still we are often deceived even under these last circumstances, and are compelled to call in the aid of sight. The blind afford us striking examples of accuracy in their perceptions by the ear. In the Belisar of Zeune, the case of a blind man is cited from Diderot; who, guided by the direction of the voice, struck his brother in a quarrel on the forehead, with a missile, which brought him to the ground.[3]

Mr. Wheatstone supposes, that the perception we have of the direc-

[1] Journal de Physiologie de Magendie, v. 367.
[2] Journal de Physiologie, v. 223.
[3] Rudolphi, Grundriss der Physiologie, S. 149, Berlin, 1823.

tion of sounds arises solely from the portion transmitted through the solid parts of the head, which, by affecting the three semicircular canals, situate in planes at right angles with each other, with different degrees of intensity, according to the direction in which the sound is transmitted, suggests to the mind the corresponding direction. If the sound be transmitted in the plane of either of the semicircular canals, the nervous matter in that canal will be more strongly acted on than that in either of the other two; and if in any plane intermediate between two of the rectangular planes, the relative intensities in these two canals corresponding therewith will vary with the direction of the intermediate plane;[1] and it has been regarded by Dr. Carpenter[2] as a powerful argument in support of this view, that in almost every instance in which these canals exist at all, they hold the same relative position to each other as in man; their three planes being nearly at right angles to one another. He properly, however, adds, that the idea must be regarded as a mere speculation, the value of which cannot be decided without an increased knowledge of the laws according to which sonorous vibrations are transmitted. If these vibrations, before reaching the ear, be deflected from their course, we are liable to deception, mistaking the echo for the direct or radiant sound.

The ideas of *magnitude* acquired by the ear are few, and to a trifling extent only. They occasionally enable the blind to judge of the size of apartments, and this they sometimes do with much accuracy. It is well known, that if a sound be confined within a small space, it appears louder than when the sonorous undulations can extend farther; hence the greater noise caused *directly* by a pistol fired in a room than in the open air. The sound *indirectly* produced will necessarily be modified by the different reflections or echoes, that may be excited. By attending to these circumstances—to the loudness of the voice and the intensity of the reverberations occasioned by the walls, and calling into aid experience under similar circumstances,—in other words, by effecting a strictly intellectual process,—the blind attain the knowledge in question.

The *velocity* of a body is indicated by the rapid succession of the vibrations that impress the ear, as well as by the change in their intensity, if the body be moving along a surface or through the air. A carriage, approaching with great velocity, is detected by the ear, from the rapidity with which the wheels strike against intervening obstacles; and by the gradual augmentation in the intensity of the sound produced. When opposite to us the intensity is greatest; and a declension gradually takes place until the sound is ultimately lost in distance.

Lastly;—by audition we form some judgment of the nature of bodies by the difference in the sounds emitted. It has been already remarked, that the *timbre* or *quality of sound* can be accurately appreciated. By this *quality* we distinguish between the sound of wood or metal; of hollow or solid bodies, &c.; but in all these cases we are compelled to call into aid our experience—without which we should be completely at a loss—and to execute a rapid, but often very complicated, intellectual operation.

[1] Journal of Science, New Series, ii. 67, London, 1827.
[2] Human Physiology, § 359, London, 1842.

Audition may be exercised *passively* as well as *actively;* hence the difference between simply *hearing*, and *listening*. We cannot appreciate, in man, the precise effects produced on the different portions of the ear by volition;—whether, for example, the advantge be limited to the better direction given to the ear, as regards the sonorous body, and to avoiding all distraction by confining the attention to the impressions made on the sense; or whether, by it, the pavilion may not be made somewhat more tense by the contraction of its intrinsic and extrinsic muscles;—whether the membrana tympani, and the membrane of the foramen ovale may be modified by the contraction of the muscles of the ossicles; or, in fine, the auditory nerve be rendered better adapted for the reception of the impression, and the brain for its appreciation. All these points are unsusceptible of direct observation and experiment; and are, therefore, enveloped in uncertainty. In some animals—as the horse—the outer ear becomes an acoustic instrument under the guidance of volition; and is capable of being turned in every direction in which a sonorous body may be placed.

Like other senses, that of hearing is largely improved by education or cultivation. The savage, accustomed, in the stillness of the forest, to listen to the approach of enemies or his prey, has the sense so delicate as to hear sounds, that are inaudible to one brought up in the din of the busy world. The blind, for reasons more than once assigned, afford examples of extreme delicacy of this as well as of their other senses. They are necessarily compelled to cultivate it more; and, lastly, the musician, by education, attains the perception of the nicest shades of musical tones; and the leader of an orchestra can detect the slightest breach in the harmony, and point out, at once, the musician who is in fault. The aptitude is laid in cerebral organization, and is developed by the education of the instrument—the ear—as well as of the encephalic or intellectual organ, without which, as we have seen, no such appreciation could be accomplished.

E. SENSE OF SIGHT OR VISION.

The immediate function of the sense of sight is to give us the notion of light and colours. Like the other senses, it is a modification of that of touch, whether we regard the special irritant—light—as an emanation from luminous bodies, or as the vibration of a subtile ethereal fluid pervading all space. Under the latter theory it would most strongly resemble the sense last considered.

The pleasures and advantages derived by the mind through this inlet are of so signal a kind as to render the organ of vision a subject of universal interest. Every one, who lays the slightest claims to a general education, has made it more or less a subject of study, and is not unfrequently better acquainted with its structure and properties than the medical practitioner. Complicated as its organization may seem, it is, in action, characterized by extreme simplicity; yet, "in its simplicity," as Dr. Arnott[1] has remarked, "so perfect, so unspeakably perfect, that the searchers after tangible evidences of an all-wise and good Creator have declared their willingness to be limited

[1] Elements of Physics, 2d Amer. edit., vol. ii. P. i. p. 161, Philad., 1836.

to it alone, in the midst of millions, as their one triumphant proof." Into this structure we shall inquire, so far as is necessary for our purpose, after having described the general properties of light; and then detail the mode in which its various functions are accomplished, and the knowledge derived by the mind through its agency.

The eye is the organ of vision. It varies materially in different animals;—in some, consisting of a simple capsule, with the final expansion of the nerve of sight distributed on its interior, and communicating externally by means of the transparent cornea, which admits the light. It is in this simple state that M. de Blainville[1] assimilates it to a bulb of hair, modified for the new function it has to execute. In man, and the upper classes of animals, the organ is much more complicated in its structure; and in it we have a still clearer example of the distinction between the physical, and the nervous or vital part of the apparatus, than in any of the other organs of sense,—the former consisting of transparent tunics, and humours, which modify the light according to the laws of optics;—the latter being a production or expansion of nervous structure, for the reception of the impression of light, and for conveying such impression to the proper part of the encephalon. There is, besides, attached to the organ, a number of accessory parts or *tutamina*, which are more or less concerned in the proper performance of the function. It will be necessary, therefore, to give a succinct view, not only of the eye, properly so called, but also of these accessory organs, which serve to lodge, move, protect, and lubricate it. The description will not, however, be clearly understood, without premising some general observations on the properties of light, especially as regards its refraction, on which the phenomena of vision are greatly dependent.

1. LIGHT.

The sun and the fixed stars are the great sources of light. It is given off, also, from substances in a state of combustion, and from phosphorescent bodies; and, by entering the eye directly, or after various reflections or refractions, impinges on the optic nerve, and gives the sensation of light.

Two main opinions have been entertained regarding the nature of light; the one, propounded by Newton—that it consists of extremely minute particles, emanating from luminous bodies; the other—that of Des Cartes, Hook, Huygens, Euler, and others,—that it is a subtile, eminently elastic fluid—an ether—pervading all space; the elastic molecules of which, when put in motion by the oscillations of bodies, impress the eye as sonorous vibrations affect the ear. It is not for us to discuss this question of higher physics. We may merely remark, that difficulties attend both hypotheses. According to that of Des Cartes, it is not easy to explain, why an opaque body should prevent the undulations from reaching the eye,—or the change of direction, which light experiences in passing from one medium into another; whilst, according to that of Newton, it is difficult to conceive, how a luminous body, as the sun, can shed its immense tor-

[1] De l'Organisation des Animaux, Paris, 1825.

rents of light incessantly, without undergoing rapid diminution; and how, with the extreme velocity of light, these particles should not be possessed of sensible momentum; for it has been found that a large sunbeam, collected by a burning-glass, and thrown upon the scale of a balance of extreme delicacy, is insufficient to disturb the equilibrium. To the hypothesis of Newton it has been objected, that the particles being reflected by thousands of bodies, and in innumerable directions, would necessarily jostle and interfere with each other. This objection is not, however, so valid as it appears at first sight. It will be seen hereafter, that the impression of a luminous object remains upon the retina for the sixth part of a second. Admitting it, however, to impress the eye for the $\frac{1}{300}$th part, three hundred particles, per second, would be sufficient to excite a constant and uniform sensation of the presence of light; and since, as we shall find, it traverses sixty-seven thousand leagues in a second of time, if we divide this by three hundred, we shall find a space of six hundred and seventy miles between each particle; a distance equal to that—in a straight line—between New York and Savannah; and if we suppose six particles to be sufficient per second, each will be separated from the other by a space of thirty-three thousand five hundred miles!

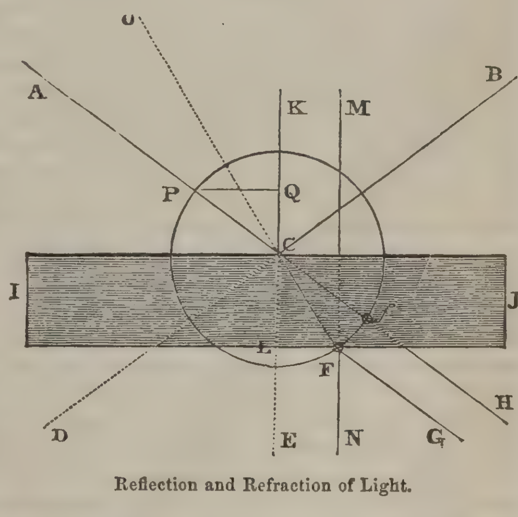
Without deciding in favour of either of the great theories, that of Newton admits of more easy application to our subject, and will, therefore, be employed in the various explanations that may be required.

Light, then, proceeding from a luminous body, impinges on the substances that are within its sphere; and these, by reflecting the whole or a part of it to the eye, become visible to us. In its course, direct or reflected, its velocity is almost inconceivable. From observations made on the eclipses of Jupiter's satellites, by Römer, Cassini, and other astronomers, it has been calculated, that the light of the sun is eight minutes and thirteen seconds in its passage from that luminary to the earth. The distance between the earth and the sun is thirty-three millions of leagues, so that the velocity of light is sixty-seven thousand leagues, or two hundred thousand miles per second; in other words, in the lapse of a single second it could pass between Washington and Albany—supposing the distance to be three hundred miles—seven hundred times; and could make the tour of the globe in the time it takes us to wink. In consequence of this extreme velocity,—in all calculations, regarding the light from bodies on the surface of the globe, it is presumed to reach the eye instantaneously; for, granting that a luminous body at Albany could be seen at Washington, the light from it would reach the eye in the $\frac{1}{700}$th part of a second. Inconceivable as this velocity is, it is far surpassed by that of the attractive force exerted between the heavenly bodies. "I have ascertained," says M. La Place, "that between the heavenly bodies all attractions are transmitted with a velocity, which, if it be not infinite, surpasses several thousand times the velocity of light; and we know that the light of the moon reaches the earth in less than two seconds." An annotator on the works of this distinguished mathematician is more definite; affirming, "that the gravific fluid passes over one million of the earth's semi-diameters in a minute of time." Its velocity is eight millions of times greater than that of light.

A series of particles, succeeding each other in a straight line, is called a *ray* of light. Light which proceeds from a radiant point, forms diverging *cones*, which would be prolonged indefinitely did they not meet with obstacles. In its course, it loses its intensity according to a law, which seems applicable to all influences radiating from a centre. If a taper be placed in the middle of a box, each one of whose sides is a foot square, all the light must impinge upon the sides of the box: if it be placed in a box, whose sides are two feet square, the light will shine upon them from double the distance, but it will be distributed over four times the surface. The intensity of the light, then, in this case, as in every other, diminishes according to the square of the distance from the luminous body. According to this rule, those planets which are nearer the sun than ours must receive the light and also the heat—for the same law applies to caloric—in much greater intensity; whilst the more distant luminaries can receive but little caloric, or light, in comparison with the earth; hence, perhaps, the necessity for the satellites by which they are accompanied, and by whose agency the light of the sun is reflected to the planet, and the deficiency in some measure compensated.

In proceeding from a luminous body, *rays*, *cones*, or *pencils of light* must traverse intermediate bodies, in order to reach the eye. These bodies are called *media*. Air is the common medium; and when, in this way, the light has attained the exterior of the organ, the farther transmission is effected through different transparent humours, which consequently form so many *media*. In its course through media, light may remain unmodified: it may proceed in the same straight line; or it may meet with an obstacle which arrests it altogether, or *reflects* it; or, again, it may traverse media of different natures and densities, and be made to deviate from its original course, or be *refracted*.

Fig. 259.



Reflection and Refraction of Light.

When a ray of light falls upon an *opaque* body, as upon a bright metallic or other mirror, it is reflected from the mirror, in such a manner, that the angle made by the incident ray with a perpendicular to the surface of the medium at the point of incidence, is exactly equal to that made by the reflected ray with the same perpendicular. Suppose I J to represent a plate of polished metal, or glass, rendered opaque by a metal spread upon its posterior surface, as in the common looking-glass. The rays, proceeding from an observer at K, will be reflected back to

him in the same line K C; that is, in a line perpendicular to C, the point of incidence. The observer will, therefore, see his own image; but, for reasons to be mentioned hereafter under optical illusions, he will seem to be as far behind the mirror as he really is before it, or at E. Suppose, on the other hand, that the observer is at A, and that a luminous body is placed at B: in order that the rays, proceeding from it, shall impinge upon the eye at A, it is necessary that the latter be directed to that point of the mirror from which a line, drawn to the eye, and another to the object, will form equal angles with the perpendicular; in other words, the angle B C K or *angle of incidence* must be equal to the *angle of reflection*, A C K. In this case, again, the object will not appear to be at B, but in the prolongation of the line A C, at H, as far from the point of incidence C as B is.

Except in the case of illusions, the study of the reflection of light or *catoptrics* does not concern vision materially. It is on the principles of *dioptrics*, that the chief modifications are effected on the progress of the light through the physical part of the organ; and, without a knowledge of these principles, the subject would be totally unintelligible. It is necessary, therefore, to dwell at some length on this topic.

Whenever a ray of light passes through *diaphanous* or *transparent* bodies of different densities, it is bent or made to deviate from its course, and such deviation is called *refraction;* the ray is said to be *refracted;* and, owing to its being susceptible of such refraction, is held to be *refrangible.* The point, at which a ray enters the medium, is called the *point of immersion;* and that, by which it issues from such medium, the *point of emergence.* Instead of considering the medium I J opaque, let it be regarded as transparent. C, in this case, will be the point of immersion for the incident rays that meet there; and L and F will be the points of emergence for the rays K E and A C F G, respectively. If a ray of light, as K C, falls perpendicularly on the surface of any medium, it continues its course through it without experiencing any modification, and emerges in the same straight line. Hence a body at L will appear in its true direction and distance to an observer at K looking directly downwards on a pool of water, I J. If, on the other hand, a ray, as A C, after having passed through air, falls obliquely upon the surface of water B;—by entering a medium of different density, it is deflected from its course; and, instead of proceeding in the direction C H, it is refracted, at the point of immersion, in the direction C F—that is, *towards* the perpendicular K E. If, again, the ray emerges at F into a medium of the same density as that through which it passed in the course A C, it will proceed in a line parallel to A C, or in the direction F G, or will wander *from* the perpendicular. The cause of this difference in the deflections produced by different media is not easy of explanation. The fact alone is known to us, that bodies refract light differently according to their densities and nature. If the light proceeds from a rarer to a denser medium, it is attracted or refracted *towards* the perpendicular; if, on the contrary, it passes from a denser to a rarer medium, it is refracted *from* the perpendicular. The ray A C proceeded from a rarer medium—the air—into a denser, I J—water; it was refracted in the direction C F, towards the perpendicular K E. On emerging at F, circumstances were re-

versed; it wandered from the perpendicular M N, and in the direction F G, parallel to A C, because the media, above and below I J, were identical. We can now understand, why water, saline solutions, glass, rock-crystal, &c., have higher refractive powers than air. They are more dense.

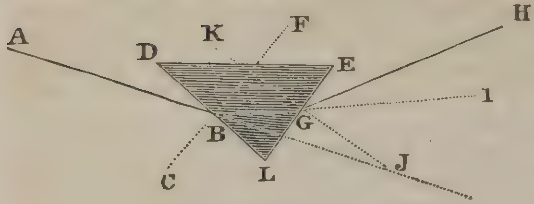
The nature or character of bodies greatly influences their refractive powers. Newton observed this in his experiments, and has furnished science with one of its proudest trophies, by his prognostic, in the then infant state of chemistry, that water and the diamond would be found to contain combustible ingredients. The diamond or *brilliant* is one of the most refractive of known substances, and this is one of the sources of its brilliancy. The opinion of Newton, it is hardly necessary to say, has been triumphantly confirmed.

This refraction of rays, that fall obliquely upon a medium, gives rise to numerous optical illusions. The ray proceeding from F, in the bent course F C A, will impinge on an eye at A; and the object F will appear to be at *f*. The pool will consequently seem shallower. In like manner, an object O in the air would not be perceptible to an eye in the water at F, in the direction O C F; whilst one at A would be distinctly visible,—the ray from it proceeding in the direction A C F, but appearing to come straight to the eye in the direction O C F.

All transparent bodies, at the same time that they refract light, reflect a portion of it. This is the cause of the reflections we notice in the glass of windows, and of the image perceptible in the eye. The same substance has always the same refractive power, whatever may be its shape:—in all cases, the sine of the angle of refraction holding the same ratio to the sine of the angle of incidence, whatever may be the incidence. The *angle of incidence* is the angle formed by the incident ray with a perpendicular raised from the point of immersion; the *angle of refraction* that formed by the refracted portion of the ray with the same perpendicular. In Fig. 259, A C K is the angle of incidence of the ray A C; and L C F the angle of refraction. The sines of these angles respectively are the lines P Q and L F. But although media may refract the rays of light equally, the form of the refracting body materially modifies their arrangement. The perpendiculars to the surface may approach or recede from each other; and if this be the case the refracted rays will approach or recede from each other likewise.

Where the body has plane and parallel surfaces, as the glass of our windows, the refraction, experienced by the ray on entering the glass, is corrected by that which occurs on its emergence; the light does not, therefore, proceed in one straight line, but in parallel lines separated by a space dependent upon the thickness of the refracting body, and the obliquity of the incident ray. If the medium be thin as in a pane of glass, the rays do not appear deflected from their original direction. In Fig. 259, the interval between the direct ray and the ray A C F after its emergence is that between G and H. If the surfaces of the diaphanous body be plane, but inclined towards each other, as in the common prism, the refraction experienced by the ray, on emerging, instead of correcting that experienced during its passage through the body, is added to it; and the rays are deflected from their course to

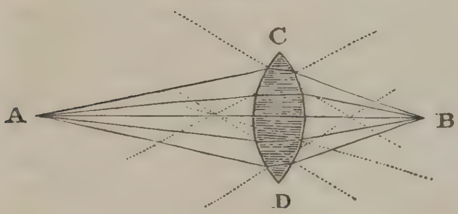
Fig. 260.



Prism.

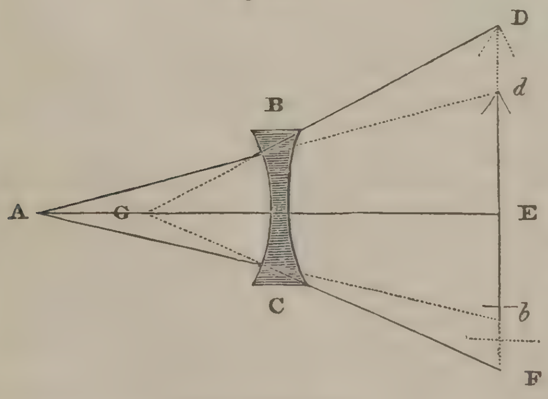
an extent equal to the sum of the two refractions. The ray A B, Fig. 260, after impinging upon the side D L of the prism at B, instead of continuing its course in the direction B J, is refracted *towards* the perpendicular C B F,—the medium being denser than air; and on emerging into the rarer medium, instead of continuing its course in the direction G I, it is refracted in the line G H, or *from* the perpendicular K J. Again, if the surfaces of the medium be convex, the rays are so situate, after refraction, as to converge behind the refracting body into a point called the *focus*, which is nearer to the medium the less the divergence of the rays, or in other words, the more distant the luminous object. Fig. 261 exhibits a pencil of rays, proceeding from a radiant point at A, and meeting at a focus at B; the dotted lines being the perpendiculars drawn to the surface at the points of immersion and emergence. Lastly; if the surfaces of the medium be concave, as in Fig. 262, the luminous rays, proceeding from a radiant point as at A, are rendered so divergent, that if we look for a focus here it must be anterior to the medium or at G.

Fig. 261.



Double Convex Lens.

Fig. 262.



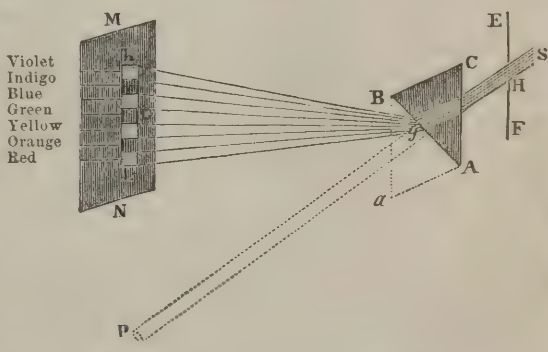
Double Concave Lens.

A knowledge of these facts has given occasion to the construction of numerous invaluable optical instruments, adapted to modify the luminous rays so as to change the situation in which bodies are seen; to augment their dimensions; and to render them more luminous and visible, when remote and minute. It is to this branch of science that we are indebted for some of the most important information and advantages that we possess in the domains

of science and art. The simplest of these instruments are bodies shaped like a lentil, and hence called *lenses*. They are composed of two segments of a sphere. The medium in Fig. 261 is a *double convex;* that in Fig. 262, a *double concave lens*. The manner in which they modify the course of the luminous rays passing through them has been sufficiently described.

The study of the refraction of light leads to the knowledge of an extremely important fact; which, when it was first made known by Newton, excited universal astonishment;—that a ray of light is itself composed of several coloured rays differing from each other in their refrangibility. If a beam of the sun's light be admitted through the hole of a window-shutter, E F, Fig. 263, into a dark chamber, it will proceed in a direct line to P, and form a white spot upon the wall, or on a whitened screen placed there for the purpose. But if a glass prism, B A C, be placed, so that the light may fall upon its surface, C A, and emerge at the same angle from its second surface, B A, in the direction *g* G, the beam will expand; and if, after having emerged, it be received on the whitened screen, M N, it will be found to occupy a considerable space; and, instead of the white spot, there will be an oblong image of the sun, K L, consisting of seven colours;—*red*, *orange*, *yellow*, *green*, *blue*, *indigo*, and *violet*. Each of these colours admits of no farther decomposition when again passed through the prism; and the whole lengthened image of the sun is called the *prismatic* or *solar spectrum*.

Fig. 263.



Prismatic Spectrum.

In this dispersion of the coloured rays, it will be observed that the red ray is the least turned from its course; and is hence said to be the least refrangible; whilst the violet is most so.

Such is the spectrum, as depicted by Newton: since his time, it has, by some, been reduced to three colours,—*red*, *yellow*, and *blue;* as certain of the colours can be composed from others,—the green, for example, from the blue and yellow. Wollaston made it to consist of four; *red*, *green*, *blue*, and *violet;* Sir J. Herschel of four; *red*, *yellow*, *blue*, and *violet:* and, more recently, Sir David Brewster has restricted it to three; *red*, *yellow*, and *blue*. The causes which have led to these various divisions, it is not our province to explain.

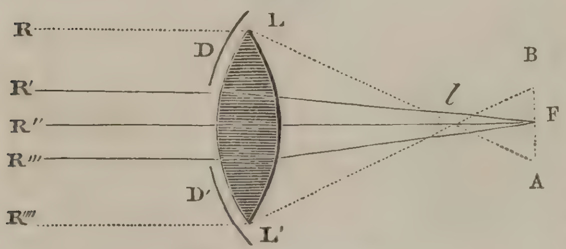
Each of the rays, of which the spectrum is composed, appears to have a different calorific and chemical action; but this also is a subject that nowise concerns the function under consideration.

The decomposition of light into its constituent rays enables us to

explain the cause of the colour of different substances. When white light impinges upon a body, the body either absorbs all the rays that compose it; reflects all; or absorbs some, and reflects others. If it reflects the whole of the light to the eye, it is of a *white* colour; if it absorbs all, or reflects none, it is *black;* if it reflects only the red ray, and absorbs all the rest, it is *red;* and so of the other colours. The cause, why one body reflects one ray, or set of rays, and absorbs others, is unknown. It is conceived to be owing to the nature and particular arrangement of its molecules; which is probable; but we are still as much in the dark as ever. It is accounting for the *ignotum per ignotius.*

Two other points require a brief notice, being intimately concerned in vision;—the *aberration of sphericity*, and *aberration of refrangibility.* It has been remarked, that rays of light—after passing through a convex lens, or medium whose surfaces are convex—converge, and are brought to a focus behind it. The whole of the rays do not, however, meet in this focus. Those that are nearest the *axis*, R″ F of the lens, Fig. 264, are refracted to a focus more remote from the lens, than those that fall on the lens at a distance from the axis. The rays R′, R″, and R‴, are brought to a focus at F, whilst the rays R L, and R⁗, L′, converge at the point *l*, much nearer the lens. In like manner, rays which fall upon the lens intermediate between the rays R and R′, will have their foci intermediate between *l* and F. This diversity of focal distances is called *spherical aberration* or *aberration of sphericity:* the distance *l* F is the *longitudinal spherical aberration;* and B A the *lateral spherical aberration*, of the lens. This aberration is the source of confusion in common lenses; and as it is dependent upon the shape of the lens, it has been obviated by forming these instruments of such degrees of curvature, that the rays, falling upon the centre or margins of the lens, may be refracted to the same focus. This is effectually accomplished by lenses, whose sections are ellipses or hyperbolas. In a common glass, the inconvenience is obviated by employing a lens of a small number of degrees, or by interposing an opaque body—called, by the opticians, a *diaphragm*—anterior to the lens, so that the rays of light can only impinge upon the central part, and consequently be refracted to the same focus. This diaphragm is present in all telescopes, and occupies the situation of the curves D and D′, so as only to admit the rays R′, R″, and R‴, to fall upon the lens. Such an apparatus, we shall find, exists in the human eye.

Fig. 264.

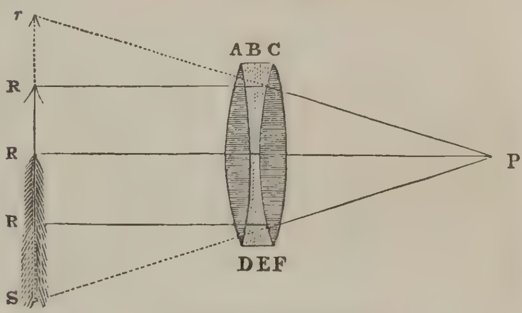


Aberration of Sphericity.

Lastly,—it has been already observed, that the different rays, constituting the solar spectrum, are unequally refrangible,—the red being the

least, the violet the most so; hence the cause of their dispersion in the spectrum. It follows from this fact, that, whenever light experiences refraction, there must be more or less dispersion of its constituent rays; and the object, seen by the refracted ray, will appear coloured. This must, of course, occur more particularly near the margins of the lens, where the surfaces become less and less parallel until they meet. The inconvenience resulting from this dispersion is called the *aberration of refrangibility* or *chromatic aberration*, and it has been attempted to be obviated by glasses, which have been termed, in consequence, *achromatic.* These are made by combining transparent bodies of different dispersive powers, in such sort, that they may compensate each other; and thus the object be seen in its proper colours, notwithstanding the refraction. Dr. Blair found, for example, that by enclosing chloride of antimony, B E, between two convex lenses of crown glass, A D and C F, the parallel rays R R and R were refracted to a single focus at P without the slightest trace of secondary colour. Newton was of opinion, that the light, in traversing a refracting medium, always experiences a dispersion of its rays, proportional to its refraction. He therefore believed, that it would be impossible to fabricate an achromatic glass. This is one of the rare cases in which that illustrious philosopher erred. Since his time—and chiefly by the labours of Mr. Dollond—instruments have been formed on the principles above mentioned, so as to greatly diminish the inconveniences sustained from the use of common lenses; although they may still not be perfectly *achromatic.* The inconvenience is farther obviated by the diaphragm in telescopes, already referred to. As the dispersion is most experienced near the margin of the lens, it shuts off the rays, which would otherwise fall upon that portion, and diminishes the extent of aberration. The human eye is achromatic. It is obviously essential that it should be so; and this result is owing to a combination of causes. It is formed of media of different dispersive powers. Its lens is constituted of layers of different densities, and it is provided with a diaphragm of singularly valuable construction.[1]

Fig. 265.



Aberration of Refrangibility.

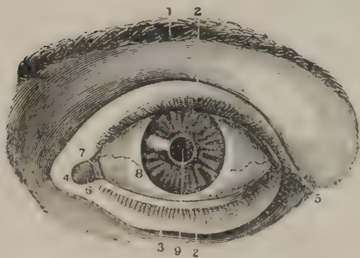
Such are the prominent points of the beautiful science of optics, that chiefly concern the physiologist as an introduction to vision. Others will have to be adverted to, as we consider the eye in action.

[1] See Listing, art. Dioptrik des Auges, in Wagner's Handwörterbuch der Physiologie iv. 451, Braunschweig, 1853; and Ludwig, Lehrbuch der Physiologie des Menschen, i. 192, Heidelb., 1853.

2. ANATOMY OF THE ORGAN OF VISION.

The human eye is almost spherical, except for the prominence at its anterior and transparent part—the *cornea.* It has been compared to a telescope, and with much propriety; as many of the parts of that instrument have been added to execute special offices, which are admirably performed by the eye—the most perfect of all optical instruments. Every telescope consists, in part, of a tube, which always comprises pieces, capable of readily entering into each other. Within this cylinder are glasses or lenses, placed in succession from one extremity to the other. These are intended to refract the rays of light, and to bring them to determinate foci. Within the telescope is a kind of partition of paper or metal, having a round hole in its centre, and usually placed near a convex glass, for the purpose of diminishing the surface of the lens accessible to the rays of light, and thus of obviating spherical aberration. The interior of the tube and of the diaphragm is coloured black, to absorb the oblique rays, which are not inservient to vision; and thus to prevent them from causing confusion. This arrangement is nearly a counterpart of that which exists in the eye. The tube of the instrument is represented by three membranes in superposition,—the *sclerotic*, *choroid*, and *retina;* the last receiving the impression of light. Within, are four refracting bodies, situate one behind the other; and intended to bring the rays of light to determinate foci,—the *cornea*, *aqueous humour*, *crystalline lens*, and *vitreous humour.* Lastly, in the interior of the eye, near the anterior surface of the crystalline, is a diaphragm—the *iris*, having an aperture in its centre—the *pupil.* These different parts demand a more detailed notice.

Fig. 266.



Front View of the Left Eye—moderately opened.

1. Supercilia. 2. Cilia of each eyelid. 3. Inferior palpebra. 4. Internal canthus. 5. External canthus. 6. Caruncula lacrymalis. 7. Plica semilunaris. 8. Eyeball. 9. Pupil.

1. *Coats of the Eye.*—Before describing the coats of the eye it may be remarked, that the eyeball is invested with a membranous tunic, which separates it from the other structures of the orbit; and forms a smooth, hollow surface by which its motions are facilitated. This investment has been variously called, *cellular capsule of the eye*, *ocular capsule*, *tunica vaginalis oculi*, and *submuscular fascia.*

The *sclerotic* is the outermost proper coat. It is that which gives shape to the organ, and which constitutes the *white of the eye.* It is of a dense, resisting, fibrous nature, belonging to what M. Chaussier calls *albugineous* tissue. Behind, it is penetrated by the optic nerve; and before, the cornea is dovetailed into it. It has, by some anatomists, been considered a prolongation of the dura mater, accompanying the optic nerve; whilst the choroid has been regarded as an extension of the pia mater; and the retina of the pulp of the nerve. The sclerotic is the place of insertion for the various muscles that move the eyeball,

and is manifestly intended for the protection of the internal parts of the organ.

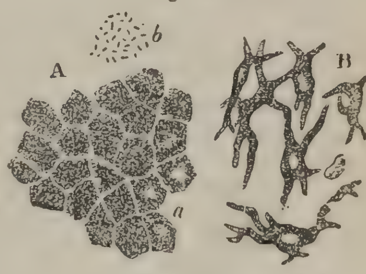
Immediately within the sclerotica, and feebly united with it by vessels, nerves, and areolar tissue,[1] is the *choroid coat;*—a soft, thin, vascular, and nervous membrane. It completely lines the sclerotic; and has, consequently, the same shape and extent. Behind, it is perforated by the optic nerve; before, it has the iris united with it; and within, it is lined by the retina, which does not, however, adhere to it,—the black pigment separating them from each other. It is chiefly composed of the ciliary vessels and nerves, and consists of two distinct laminæ, to the innermost of which Ruysch—the son—gave the name *membrana Ruyschiana.* In fishes these laminæ are very perceptible, being separated from each other by a substance, which M. Cuvier considers to be glandular. The choroid is impregnated and lined by a dark-coloured mucous pigment, *stratum pigmenti, pigmentum nigrum.* In some cases, as in the *albino,* this substance, which is exhaled from the choroid, is light-coloured, approximating to white. Leopold Gmelin[2] conceives that it approaches the nature of indigo; Dr. Young,[3] regards it as a mucous substance, united to a quantity of carbonaceous matter, upon which its colour depends; and Berzelius,[4] from his chemical investigations, considers it to consist chiefly of carbon and iron; but Professor Jacob thinks it obviously an animal principle *sui generis,* its elements being oxygen, hydrogen, carbon, and nitrogen. Dr. Apjohn found 100 parts, in a dry state, leave, when incinerated, 4·46 of a calx consisting of chloride of calcium, carbonate of lime, phosphate of lime, and peroxide of iron. Mr. Thomas Wharton Jones has examined the layer of black pigment

Fig. 267.

Choroid Coat of the Eye.

1. Curved lines marking the arrangement of venæ vorticosæ. 2, 2. Ciliary nerves. 3. A long ciliary artery and nerve. 4. Ciliary ligament. 5. Iris. 6. Pupil.

Fig. 268.



Pigmentum Nigrum.

A. Choroid epithelium, with the cells filled with pigment, except at *a*, where the nuclei are visible. The irregularity of the pigment-cells is seen. *b*. Grains of pigment.
B. Pigment-cells from the substance of the choroid. A detached nucleus is seen.—Magnified 320 diameters.

[1] In the situation of this areolar tissue, Arnold describes a serous membrane, *Spinnwebenhaut, Arachnoidea oculi, Lamina fusca scleroticæ.*—Arnold über das Auge, Tab. iii., Fig. 2, and Weber's Hildebrandt's Handbuch der Anatomie, iv. 68, Braunschweig, 1832.

[2] Dissert. Sistens Indagationem Chemicam Pigmenti Nigri Oculorum Taurorum, Gotting., 1812.

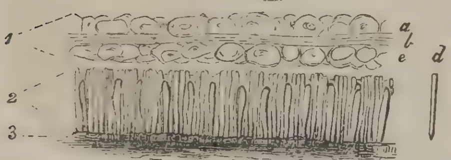
[3] Medical Literature, p. 521, Lond., 1813.

[4] Medico-Chirurg. Trans., iii. 225.

on the inner surface of the choroid microscopically. He states that it possesses organization, and constitutes a real membrane—*pigmental membrane*—consisting of very minute flat bodies of an hexagonal form, joined together at their edges.[1] It is generally considered to consist of pigment cells, which form a kind of pavement, and are somewhat of a polyhedral shape; lying in a very regular manner, with some intercellular substance between them.

On the outer side of the bottom of the cavity of the eye, there is a small shining space, destitute of pigment, through which the colours of the membrana Ruyschiana appear. This is termed *tapetum.* It is met with only in quadrupeds.

Fig. 269.



A. An Enlarged Plan of the Retina, in section.

1. The nervous structure, viz., the nerve-fibres (*b*) between nerve-cells (*a*, *c*). 2. Jacob's membrane. 3. Inner surface of choroid. *d.* One of the small pointed bodies of Jacob's membrane.

B. The Outer Surface of Jacob's Membrane.

Opposite *e*, the twin cones are obscurely seen, not being in focus, while, at the lower part of the figure, near *f*, the same bodies are clearly discernible. Towards the right side of the figure, where the objects are disturbed, the twin cones project like papillæ, at *g*, the small rods being in a great measure lost at this place. And these (small bodies) are seen to become horizontal towards the extremity of the object, *h*, where some are in disorder.

The *retina* is the last coat, if we except a highly delicate serous membrane—discovered by Dr. Jacob,[2] of Dublin, and called after him *Tunica Jacobi*,—which is interposed between the retina and the choroid coat.[3] It appears to be composed of cylindrical, transparent, and highly refractive bodies, which are arranged perpendicularly to the surface of the retina,—their outer extremities imbedded, to a greater or less depth, in a layer of the pigmentum nigrum. They form the bacillar layer of the retina of other observers. The only plausible suggestion, which, according to Messrs. Kirkes and Paget,[4] has been offered, concerning the use of these bodies, is that of Brücke, who thinks it not unlikely, that they may serve to conduct back to the sensitive portion of the retina those rays of light which have traversed that membrane, and have not been entirely absorbed by the pigmentum nigrum. Mr. George H. Fielding, of Hull,[5] has affirmed, that immediately behind the retina, and in connexion with it, there is a peculiar membrane, separable into distinct layers

[1] Art. Eye, by Dr. Jacob, in Cyclop. of Anat. and Physiol., Part x. p. 181, for June, 1837.

[2] Philosoph. Transact. for 1819; Medico-Chirurg. Transactions, xii., Lond., 1823, and Art. Eye, in Cyclop. of Anat. and Phys., p. 186.

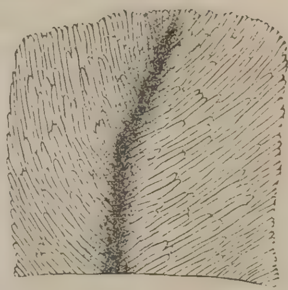
[3] Philosophical Transactions for 1829, p. 300.

[4] Manual of Physiology, 2d American edition, p. 415, Philadelphia, 1853.

[5] Second Report of the British Association for the Advancement of Science; or Amer. Journal of the Med. Sciences, Nov., 1833, p. 220.

from the choroid, and supplied with bloodvessels, which he proposes to name *membrana versicolor*. He presumes, that it receives the vibrations of light, and communicates them to the retina: the eyes, used for experiment, were those of the ox and sheep.

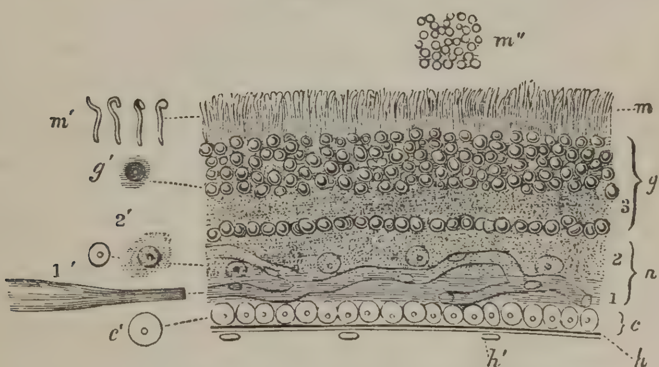
Fig. 270.



Part of the Outer Surface of the Retina of the Frog, showing the imbricated arrangement of the bacillar layer or Jacob's membrane.—Magnified 300 times.

The retina lines the choroid, and is a soft, thin, pulpy, and grayish membrane, formed chiefly, if not wholly, by the final expansion of the optic nerve. M. Ribes,[1] indeed, esteems it a distinct membrane, on which the optic nerve is distributed;—a structure more consistent with analogy. On its inner surface it is in contact with the membrane of the vitreous humour; but they are not adherent. Anteriorly, it terminates near the anterior extremity of the choroid, forming a kind of ring, from which an extremely delicate lamina is given off. This is reflected upon the ciliary processes; dips into the intervals separating them, and, according to some anatomists, passes forward as far as the crystalline. Modern observers—Messrs. B. C. R. Langenbeck, Treviranus, Gottsche, Volkmann, E. H. Weber, Michaelis, and others, have examined minutely into the anatomy of the retina, and have shown that it consists of several layers:—Langenbeck says three; Michaelis, four. The inner or fibrous lamina or layer of the true retina is considered to be formed by the optic nerve, which, at its entrance into the eye, divides into numerous small fasciculi of

Fig. 271.



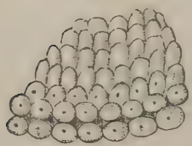
Vertical Section of the Human Retina and Hyaloid Membrane.

h. Hyaloid membrane. *h′*. Nuclei on its inner surface. *c*. Layer of transparent cells, connecting the hyaloid and retina. *c′*. Separate cell enlarged by imbibition of water. *n*. Gray nervous layer, with its capillaries. 1. Its fibrous lamina. 2. Its vesicular lamina. 1′. Shred of fibrous lamina detached. 2′. Vesicle and nucleus detached. *g*. Granular layer. 3. Light lamina frequently seen. *g′* Detached nucleated particle of the granular layer. *m*. Jacob's membrane. *m′*. Appearance of its particles, when detached. *m″*. Its outer surface.—Magnified 320 diameters.

[1] Mémoir. de la Société Médicale d'Emulation, vii. 86.

ultimate fibrils, that spread themselves out, so as to form a net-like plexus. From this plexus, the fibres of which lie in the plane of the surface of the vitreous humour, a very large number of fibrils arises in a direction perpendicular to the surface, so as to be all directed towards the centre of the eye. These pass through a delicate layer of areolar tissue, containing a minute plexus of bloodvessels, and from this every fibril receives a sheath, which envelopes its extremity, and thus forms a minute papilla. The surface of the retina, in contact with the vitreous humour, is wholly composed of these papillæ, which are closely set together; and have been regarded as identical with the globules of the retina of Weber.[1] The diameter of these globules in man, according to Weber, is from the $\frac{1}{8000}$th to $\frac{1}{8400}$th of an inch.

Fig. 272.



Papillæ of the Retina of the Frog, seen from the side turned towards the vitreous humour.

The four higher rows are seen sideways.—Magnified 300 times.

The arrangement of the constituent laminæ or layers of the retina, as given by Todd and Bowman,[2] is represented in Fig. 271; whilst Fig. 273 depicts them as pointed out by H. Müller and Kölliker.[3] There is much yet to learn, however, in regard to the exact constitution of the retina, and the histology and functions of its special parts in the exercise of vision, on which opinions are at this time very unsettled.[4]

About a sixth of an inch on the outside of the optic nerve, and in the direction of the *axis* of the eye, or of a line drawn perpendicularly through the centre of the cornea, is a *yellow spot*, about a line in extent, having a depression in its centre. This spot and depression are the *limbus luteus* or *macula lutea*, and *fovea centralis*, *fovea optica* or *foramen centrale* of Sömmering.[5] The yellow spot does not exist in the fœtus;[6] and the folds, described by Sömmering as surrounding the yellow spot, would appear to be a *post mortem* appearance. In the examination of two convicts, three hours after execution, the foramen was not seen satisfactorily.[7]

The retina receives many blood-vessels, which proceed from the

[1] Carpenter, Human Physiology, p. 262, Lond., 1842.

[2] The Physiological Anatomy and Physiology of Man, Amer. edit., p. 414, Philad., 1850.

[3] Mikroskopische Anatomie, 2ter Band, S. 648, Leipz., 1854; or Amer. edit. of Sydenham Society's edition of Kölliker's Manual of Human Histology, by Dr. Da Costa, p. 739, Philad., 1854.

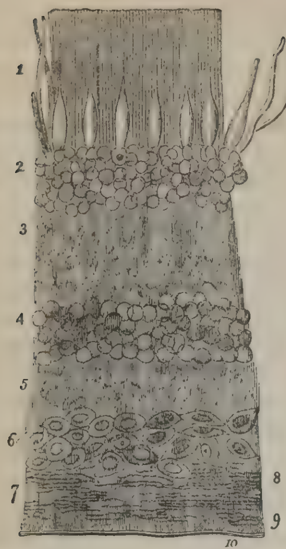
[4] See, on this subject, Todd and Bowman, and Kölliker, in op. cit.; Günther, Lehrbuch der Physiologie des Menschen, von Dr. Otto Funke, 2ter Bd., 2ter Abth., S. 479, Leipz., 1853; and for the opinions of Gegenbaur, Leydig and Virchow, see Dr. Robert T. Lyons, Annals of Micrology, in Brit. and For. Med.-Chir. Rev., April, 1855, p. 561; for those of Remak, Canstatt's Jahresbericht, im Jahre, 1854, 1er Bd., S. 56, or Dr. John W. Ogle's Report on Micrology, in Brit. and For. Med.-Chir. Rev., Oct., 1855, p. 524; and for those of Prof. Goodsir, Edinb. Med. and Surg. Journ., Oct., 1855, or Amer. Journ. of the Med. Sciences, Jan., 1856, p. 189.

[5] Sömmering, in Comment. Societ. Gotting., tom. xiii. 1795–98; A. ab Ammon, de Genesi et Usu Maculæ Luteæ, &c., Vinar., 1830.

[6] Rudolphi, Grundriss der Physiologie, B. ii. Abtheil, 1, S. 176, Berlin, 1823.

[7] W. E. Horner, Special and General Anatomy, 5th edit., p. 426, Philad., 1839, J. Pancoast in Wistar's Anatomy, 8th edit., Philad., 1842, and Bergmann, in Henle's und Pfeuffer's Zeitschrift, v. 245; cited by Lyons in op. cit.

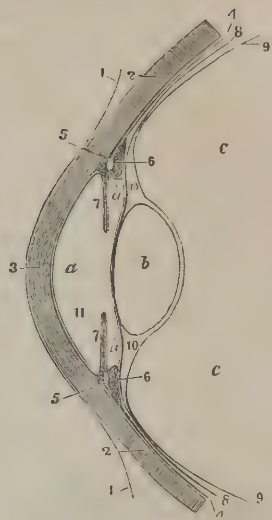
Fig. 273.



Vertical Section of Retina of the Human Eye.

1. Bacillar layer. 2. Outer layer granular. 3. Intermediate, fibrous layer. 4. Inner granular layer. 5. Finely granular gray layer. 6. Layer of nerve-cells. 7. Layer of fibres of optic nerve. 8. Limitary membrane.

Fig. 274.



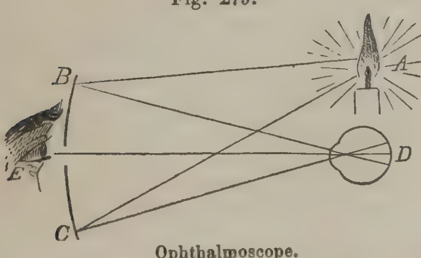
Plan of the Structures in the Fore Part of the Eye, seen in section.

1. Conjunctiva. 2. Sclerotica. 3. Cornea. 4. Choroid. 5. Annulus albidus; before this is seen the canal of Fontana. 6. Ciliary processes. 7. Iris. 8. Retina. 9. Hyaloid membrane. 10. Canal of Petit (made too large). 11. Membrane of the aqueous humour (too thick). *a.* Aqueous humour: anterior chamber and (*a*) posterior chamber. *b.* Crystalline lens. *c.* Vitreous humour.

central artery of the retina or *of Zinn.* This vessel—it is important to observe—enters the eye through the centre of the optic nerve, the *porus opticus*, and, before passing directly through the vitreous humour, sends off lateral branches to the retina.[1]

By means of a recently invented instrument, the ophthalmoscope, Fig. 275, the interior of the eyeball may be well seen. The luminous rays from an object at A are made to fall on a perforated reflector B C, and come to a focus so as to illuminate the retina. Some of these rays are reflected back, so as to enable an eye at E to observe the illumination. The bottom of a healthy eye is, in this manner, observed to be of a yellowish-red colour,—the colour being brighter in the immediate vicinity of the optic centre than in other parts of the retina. The tint will vary in different eyes according to the hue of the pigmentum nigrum. Close to the inner side of the entrance of the optic nerve the colour is darker at one point; which has been ascribed by

Fig. 275.



Ophthalmoscope.

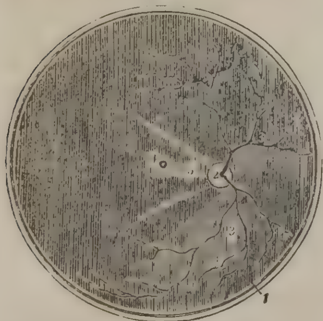
[1] See, on the vessels of the globe of the eye, Dr. C. Sappey, Mém. de la Société de Biologie, Année, 1854, p. 243, Paris, 1855.

Helmholtz to the shadow of the semilunar fold of the retina. When the patient looks directly at the eye of the observer, and thus brings the axis of the eyes in the same line, the yellow spot of Sömmering is perceived. The retina is there of a grayish yellow colour entirely free from any admixture of red; and no blood-vessels are seen on its surface.[1]

2. *Diaphanous parts of the Eye.*—The parts that act as refracting bodies are either transparent membranes, or fluids contained in capsules, which give them a fixed shape. These parts are the *cornea*, *aqueous humour*, *crystalline*, and *vitreous humour*.

The *cornea* is the convex transparent part of the eye, advancing in front of the rest of the organ, as a watch-glass does before the case; and appearing like the segment of a smaller sphere superadded to a larger. It was, for a long time, considered to be a prolongation of the sclerotic; but they are manifestly distinct membranes, being separable by maceration. The posterior surface is concave, and, between it and the iris, is the small space occupied by the aqueous humour, called *anterior chamber of the eye.* The cornea is generally considered to be composed of several thin laminæ in superposition, which have been compared to horn; and hence the name of the membrane; but Mr. T. Wharton Jones[2] denies this, and describes it as consisting merely of interweaving bundles of fibres. Like corneous tissue in general, it possesses neither blood-vessels nor nerves. In animals the density and convexity of the cornea vary with the media in which they live, and with the condition of the other refractive parts of the eye. In old age, the membrane is harder, tougher, and less transparent than in youth; and it frequently becomes completely opaque in its circumference, presenting the appearance called *arcus senilis*,—in German, Greisenbogen. Nerves have been traced into the substance of the cornea. They are ramifications of the ciliary.[3]

Fig. 276.



Posterior Segment of Transverse Section of the Globe of the Eye seen from within.

1. Divided edge of three tunics. The membrane covering the whole internal surface is the retina. 2. Entrance of optic nerve with arteria centralis retinæ piercing its centre. 3, 3. Ramifications of arteria centralis. 4. Foramen of Sömmering, in centre of axis of eye; the shade from sides of the section obscures the limbus luteus which surrounds it. 5. A fold of the retina, which generally obscures the foramen of Sömmering after the eye has been opened.

The *aqueous humour* is a slightly viscid fluid, which occupies the whole of the space between the posterior surface of the cornea and the anterior surface of the crystalline. This space is divided by the iris into two chambers—an *anterior* and a *posterior*—the latter being the small in-

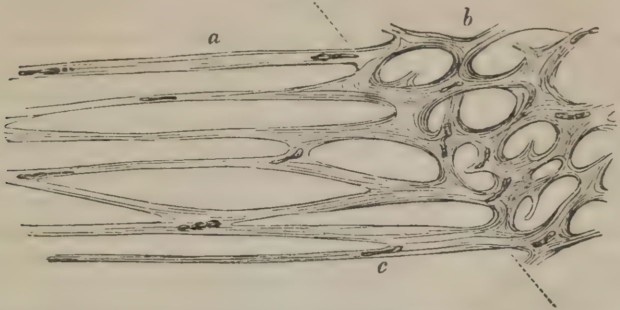
[1] T. Wharton Jones, Report on the Ophthalmoscope in Brit. and For. Med.-Chir. Rev., Oct., 1854, p. 549; Dr. Hays, in his edition of A Treatise on Diseases of the Eye, by W. Lawrence, F. R. S., Amer. edit., p. 567, Philad., 1854; and Dr. Addinell Hewson, in A Practical Treatise on the Diseases of the Eye, by William Mackenzie, M. D., Amer. edit., p. xl., Philad., 1855.

[2] Introduction to W. Mackenzie's Practical Treatise on Diseases of the Eye, Lond., 1840. In the 4th English edition, Mr. Jones remarks, that it "can scarcely be said to be formed of distinct membranes." Amer. edit., by Dr. Addinell Hewson, p. xxv. Philad., 1855.

[3] **Lond. Med. Gaz., Oct., 1845, cited from Müller's Archiv.**

terval between the hinder surface of the iris, and the anterior surface of the crystalline. Sir David Brewster[1] erroneously asserts that the

Fig. 277.

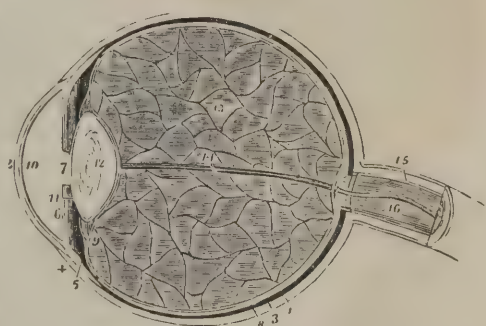


Vertical Section of the Sclerotic and Cornea, showing the continuity of their tissue between the dotted lines.

a. Cornea. *b*. Sclerotic. In the cornea, the tubular spaces are seen cut through, and in the sclerotic, the irregular areolæ. Cell-nuclei, as at *c*, are seen scattered throughout, rendered more plain by acetic acid.—Magnified 320 diameters.

posterior chamber contains the crystalline and vitreous humours; and Dr. Arnott,[2] that the anterior and posterior chambers of the eye are the compartments before and behind the crystalline. Anatomists are not agreed, whether the aqueous humour have a proper membrane, which secretes it; or whether it be not an exhalation from the vessels of the iris and ciliary processes. M. Ribes derives it from the vitreous humour. Howsoever secreted, it is very rapidly regenerated when evacuated; as it must be in every operation for cataract by extraction. It is not lodged in cells; and hence readily flows out when the cornea is punctured. The quantity of aqueous humour, in the adult, is about five or six grains. Its specific gravity is not rigorously determined, but it differs slightly from that of water, being a little greater. According to Berze-

Fig. 278.



Longitudinal Section of the Globe of the Eye.

1. Sclerotic, thicker behind than in front. 2. Cornea, received within anterior margin of sclerotic, and connected with it by means of a bevelled edge. 3. Choroid, connected anteriorly with (4) ciliary ligament, and (5) ciliary processes. 6. Iris. 7. Pupil. 8. Third layer of eye, retina terminating anteriorly by abrupt border at commencement of ciliary processes. 9. Canal of Petit, encircles the lens (12); the thin layer in front of this canal is the zonula ciliaris, a prolongation of vascular layer of retina to the lens. 10. Anterior chamber of eye containing aqueous humour; the lining membrane, by which the humour is secreted, is represented in diagram. 11. Posterior chamber. 12. Lens, more convex behind than before, enclosed in its proper capsule. 13. Vitreous humour enclosed in hyaloid membrane, and in cells formed in its interior by that membrane. 14. Tubular sheath of hyaloid membrane, which serves for the passage of the artery of capsule of the lens. 15. Neurilemma of optic nerve. 16. Arteria centralis retinæ, embedded in the centre.

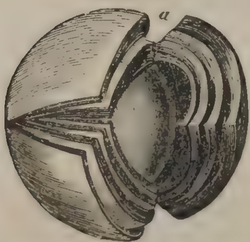
[1] A Treatise on Optics, edit. cit., p. 241.

[2] Elements of Physics, &c., 2d Amer. edit., vol. ii. P. i. p. 162, Philad., 1836.

lius, it is composed of water, 98·10; a little albumen; chlorides and lactates, 1·15; soda, with a substance soluble in water, 0·75.

The *crystalline lens* is a small body, of a crystalline appearance, and lenticular shape,—whence its name. Its diameter, in the adult, is from four lines to four lines and a half; its axis or thickness about two lines or two and a half lines. It is situate between the aqueous and vitreous humours; and at about one-third of the antero-posterior diameter of the organ. A depression at the anterior surface of the vitreous humour receives it; and a reflection of the proper membrane of the humour passes over it. The crystalline is surrounded by its *capsule*, the interior of which is bathed by a slightly viscid and transparent secretion, called *liquor Morgagnii.* Kölliker and others deny the presence of a true liquor Morgagnii during life; but its existence is defended by Lohmeyer.[1]

Fig. 279.



Lens, hardened in spirit and partially divided along the three interior planes, as well as into lamellæ.—Magnified 3¼ diameters.

Fig. 280.

Front View of the Crystalline Humour or Lens, in the Adult.

Fig. 281.

Side View of the Adult Lens.
1. Its anterior face. 2. Its posterior face. 3, 3. Its circumference.

The lens is more convex behind than before; the radius of its anterior surface being, according to Sir David Brewster,[2] 0·30; and that of its posterior surface 0·22 of an inch. It consists of a number of concentric ellipsoid laminæ, increasing in density from the circumference to the centre. Some fibres detach themselves from the different laminæ; pass to those immediately beneath, and constitute the sole bond of union that exists between them. Of old it was believed that the crystalline was of a muscular structure, and capable of modifying its own convexity, so as to adapt the eye to different distances. This was the opinion of Des Cartes; and it has more recently been received, with modifications, by Dr. Young.[3] Its muscularity is, however, by no means established, although its fibrous character is unquestionable.

The specific gravity of the human crystalline is said by Chenevix[4] to be 1·0790. He considered it to be composed chiefly of albumen. According to an analysis, however, of Berzelius,[5] it would appear to contain 35·9 parts in the hundred of a matter analogous to the colouring matter of the blood.

The *vitreous humour*, so called in consequence of its resemblance to glass, occupies the whole of the cavity of the eye behind the crystalline. It is convex behind; concave before; and is invested by a delicate, thin, transparent membrane, called *tunica hyaloidea*, which furnishes prolongations internally, that divide it into

[1] Zeitschrift für ration. Med. Bd. v. Heft i. p. 56; cited by Dr. Day, in Brit. and For. Med.-Chir. Rev., Oct., 1855, p. 520.
[2] Op. citat., p. 242. See, also, Philos. Transact. for 1835, p. 366.
[3] Philos. Transact. for 1793, p. 169; and Med. Literature, p. 521, Lond., 1813.
[4] Philos. Transact. for 1803 p 195.
[5] Medico-Chirurgical Transact., iii. 253.

cells. It is owing to this arrangement of the membrane, and not to the density of the humour, that it has the tenacity of the white of egg. Its density does not differ materially from that of the aqueous humour;—their specific gravities being stated at 1·0009, and 1·0003 respectively. The cells, formed by the hyaloid membrane, are not all of the same shape and size. They communicate freely with each other, and are well represented in Fig. 278. At the anterior part, where the hyaloid membrane reaches the margin of the crystalline, it is separable into two laminæ; one of which is reflected over the anterior; the other over the posterior surface of the lens. Between these laminæ, and at their junction round the crystalline, a canal exists, into which air may be introduced; when it exhibits a plaited arrangement, and has been called *bullular canal of Petit;*[1] and, by the French writers, *canal godronné*, or simply *canal of Petit.* This canal is generally conceived to be devoid of aperture; but Jacobson affirms, that it has, in its sides, a number of minute foramina, which admit the entrance and exit of the aqueous humour.

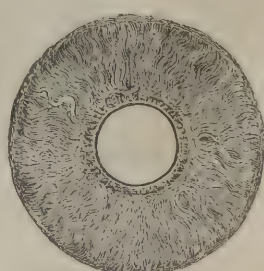
Fig. 282.

Internal View of the Iris.

The composition of the vitreous humour, according to Berzelius,[2] is as follows:—Water, 98·40; albumen, 0·16; chlorides and lactates, 1·42; soda, with an animal matter, soluble only in water, 0·02. Its absolute weight is fifteen or twenty times greater than that of the aqueous humour.

3. It was remarked, in the comparison drawn between the eye and a telescope, that a diaphragm exists in the former, called *iris*, and sometimes *uvea.* Generally, however, the latter term is appropriated to the posterior lamina of the iris. By some anatomists, the iris is conceived to be a prolongation of the choroid; by others, to consist of a proper membrane, of a muscular character; and, by others, again, to be essentially vascular and nervous; the vessels and nerves being distributed on an erectile tissue.[3] There is, in the views of anatomists and physiologists, much discrepancy regarding the structure and functions of this portion of the eye. M. Edwards,[4] of Paris, affirms, that it consists of four laminæ, two of which are extensions of laminæ composing the choroid; a third belongs to the membrane of the aqueous humour, and is reflected over its anterior surface; the fourth is the proper tissue of the iris. M. Magendie[5] asserts, that the

Fig. 283.



External View of the Iris.

[1] Mémoires de l'Académie des Sciences, Paris, 1723 and 1728; and Haller, Element. Physiol., xvi. 2, 18.

[2] Medico-Chirurgical Transactions, iii. 253.

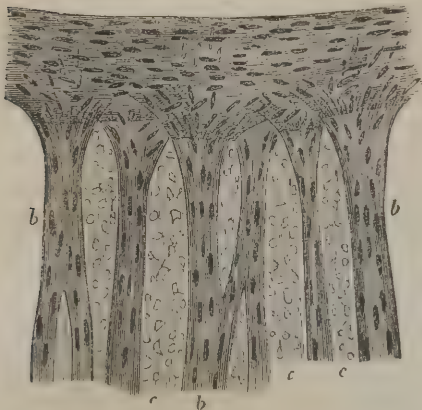
[3] Lepelletier, Physiologie Médicale et Philosophique, tom. iii. p. 158, Paris, 1832.

[4] Bullet. de la Société Philom., etc., 1814, p. 81.

[5] Op. citat., i. 61.

most recent anatomical investigations prove the iris to be muscular, and composed of two sets of fibres;—the outermost radiating, whose office is to dilate the pupil—*dilatator iridis* seu *pupillæ;* the innermost circular and concentric—*sphincter iridis* seu *pupillæ*—for the purpose of contracting it.

Fig. 284.

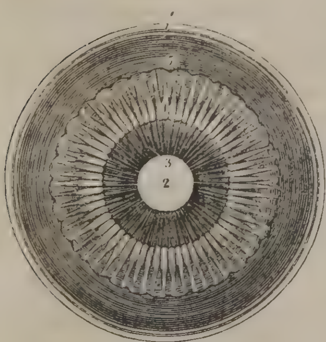


Muscular Structure of the Iris of a White Rabbit.

a. Sphincter of the pupil. *b, b.* Radiating fasciculi of dilator muscle. *c, c.* Connective tissue with its corpuscles.

The arrangement of these fibres is represented in Fig. 282, which is an internal view of the human iris magnified three diameters; and Fig. 283, an external view, exhibiting the surface to consist essentially of a plexus of bloodvessels. Both are taken from the microscopic investigations of Mr. Bauer and Sir Everard Home.[1] Its structure is now generally admitted to be muscular, and of the non-striated or unstriped variety. Kölliker[2] has recently proved experimentally the existence of a dilator muscle of the pupil. He removed the cornea and the sphincter of the iris of an albino rabbit; and applied feeble galvanic streams to the remaining portion of the iris. Dilatation of the pupil with convexity of the anterior surface of the iris was the result of repeated experiments.

Fig. 285.



Anterior Segment of a Transverse Section of the Globe of the Eye seen from within.

1. Divided edge of the three tunics; sclerotic, choroid (the dark layer), and retina. 2. Pupil. 3. Iris, the surface presented to view in this section being the uvea. 4. Ciliary processes. 5. Scalloped anterior border of the retina.

The vessels and nerves of the iris are ramifications of the ciliary,—the nerves arising from the ophthalmic ganglion and nasal branch of the fifth pair. Berzelius[3] affirms, that the iris has all the chemical characters of muscle.

The iris is the coloured part of the eye seen through the transparent cornea; and, according to the particular colours reflected from it, the eye is said to be blue, gray, hazel, &c. In its centre is an opening, called *pupil,* through which alone the rays of light can reach the lens. This opening can be enlarged or contracted by the contraction or dilatation of the iris; and in this

[1] Lectures on Comparative Anatomy, Lond., 1814—1828; and Mr. Bauer, Philosophical Transactions for 1822, p. 78.

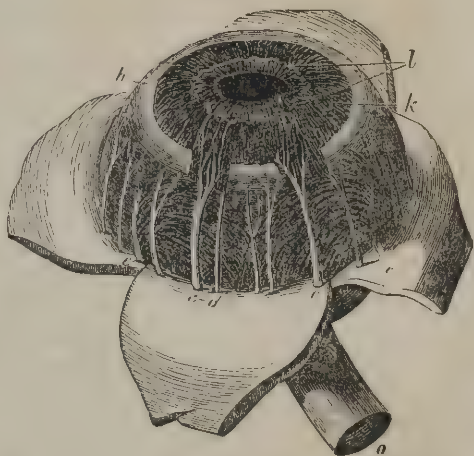
[2] Zeitschrift für Zoologie, vi. 143; and Brit. and For. Med.-Chir. Rev., Jan., 1856, p. 236.

[3] View of the Progress of Animal Chemistry, p. 86, Lond., 1843.

respect it is perpetually varying, according to circumstances. In man, the pupil is circular; but it differs greatly in its dimensions and shape in different animals. On the posterior surface of the iris—the uvea—pigmentum nigrum exists, as on the choroid. This layer has likewise some effect in giving colour to the eye: in blue eyes, for instance, the tissue of the iris is nearly white,—the pigmentum which appears through it being the chief cause of the coloration.

At the point of junction between the iris and choroid coat, they are united to the sclerotica by a band of areolar substance, called *ciliary ligament:* and from the anterior margin of the choroid, where it unites with the base of the iris, numerous vasculo-membranous appendages arise, which appear to be prolongations of the anterior margin of the choroid, turning inwards towards the margin of the crystalline lens, and terminating abruptly, without being attached to that body. They are the *ciliary processes.* These beautiful appendages are from sixty to eighty in number; and resemble the disk of a radiated flower—*corpus ciliare.* On their posterior surface, they are covered by the same kind of pigment as that on the choroid and uvea; and they impart a stain to the membranes of the crystalline and vitreous humours. The greatest diversity of opinion, here again, exists regarding both structure and function. By some, the processes have been esteemed nervous; by others, muscular;[1] glandular; and vascular. Sir Everard Home asserts, on the authority of microscopic observations by Mr. Bauer,[2] that between the processes are bundles of muscular fibres of considerable length, which originate all around from the capsule of the vitreous humour; pass forward over the edge of the lens; are attached firmly to its capsule, and there terminate. They are unconnected with the ciliary processes, or iris, and he conceives that their contraction will pull the lens towards the retina. The existence of unstriped muscular fibres in them is confirmed by the observations of Wagner, Todd and Bowman, and others.[3]

Fig. 286.



Choroid and Iris, exposed by turning aside the Sclerotica.

c, c. Ciliary nerves branching in the iris. *d.* Smaller ciliary nerve. *e, e.* Vasa vorticosa. *h.* Ciliary ligament and muscle. *k.* Converging fibres of the greater circle of the iris. *l.* Looped and knotted form of these near the pupil, with the converging fibres of the lesser circle of the iris within them. *o.* The optic nerve.

[1] Hyrtl, Lehrbuch der Anatomie des Menschen, &c., S. 408, Prag., 1846.

[2] Op. citat., and Philosoph. Transact. for 1832, p. 78.

[3] Baly and Kirkes, Recent Advances in the Physiology of Motion, the Senses, Generation, and Developement, p. 25, Lond., 1848.

Of late years, the *ciliary muscle* has been described as a grayish semitransparent ring of non-striated muscular fibres, which covers the outside of the corpus ciliare; and, by its contraction, can draw the ciliary processes forwards, and advance the lens. Dr. Clay Wallace,[1] of New York, who was one of the early describers of this muscle, and did the author the favour to demonstrate it to him, is of opinion, that its fibres, when they contract, compress the ciliary veins, and thus produce turgescence of the ciliary processes which occasions the movement of the lens. It appears to be the same muscle as the tensor muscle of the choroid—*tensor choroideæ*—of some anatomists.[2]

Fig. 287.

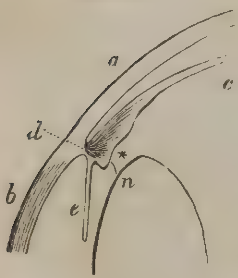


Diagram to show the Position and Action of the Ciliary Muscle.

a. Sclerotic. *b.* Cornea. *c.* Choroid, separated a little from the sclerotic. *d.* Situation of the ciliary ligament, and point from which the ciliary muscle radiates. *e.* Iris. *n.* Lens, connected with the ciliary processes by the anterior wall of the canal of Petit, the situation of which is marked by the *.—Magnified 3 diameters.

Such is an anatomical view of the physical part of the eye proper, so far as is necessary for the physiological inquirer. We have yet to consider the most important part of the organ;—that which is essentially nervous and vital in its action; and which, as we have seen, goes to constitute one of the membranes of the eyeball—the retina.

The *optic nerves—second pair* of Willis—arise from the anterior part of the *optic lobes*—corpora quadrigemina[3]—and not, as was at one time universally believed, from the *thalami nervorum opticorum.* Setting out from this point, they proceed forwards towards the thalami, to which they adhere; receiving filaments from the *corpus geniculatum externum*, an eminence a little anterior to, and on the outside of, the corpora; and from a layer of cineritious substance, situate between the point of junction of the nerve of each side and the eminentiæ mammillares—called *tuber cinereum.*[4] Proceeding forward towards the eye, the nerves approach, and form a junction at the *sella turcica*, or on the upper surface of the sphenoid bone. Anterior to this point they diverge,—each passing through the optic foramen to the corresponding eye; piercing the sclerotic and choroid at a point about one-tenth of an inch from the axis of the eye on the side next the nose, where it has a button-like appearance; and expanding to form the whole, or a part of the retina (see page 60). When the optic nerve is regarded from the inside, after removing the retina and choroid, it appears in the form of a circular spot, perforated with small holes, from which medullary matter may be expressed. This is the *lamina cribrosa* of Albinus. M. Lassaigne has examined the chemical composition of the optic nerve and retina; and concludes, from his experiments, that the retina is formed of the

[1] A Treatise on the Eye, p. 53, 3d edit., New York, 1841; and The Accommodation of the Eye to Distances, p. 14, New York, 1850.

[2] Ruete, in Wagner's Handwörterbuch der Physiologie, 16te Lieferung, S. 297, Braunschweig, 1847; and Todd and Bowman, The Physiological Anatomy and Physiology of Man, Amer. edit., p. 412, Philad., 1850.

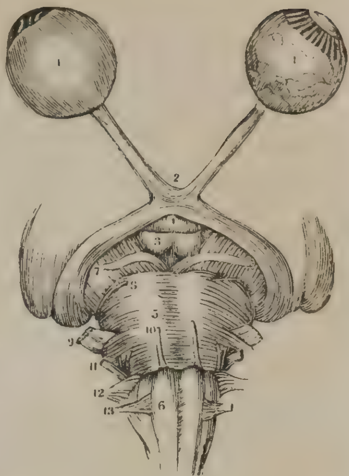
[3] A pathological case illustrating this origin, by G. Kennion, M. D., is in Lond. Med. Gaz., Sept., 1838.

[4] Solly, Lond. Med. Gazette, Sept. 24, 1838.

same elements as the cerebral and nervous substance; differing only in the proportion of constituents.

It is a question that has often been agitated, whether the optic nerves, at their junction on the sella turcica, simply lie alongside each other, or decussate, so that the root of the nerve of the left eye is on the right side, and that of the right on the left. Anatomical investigations have, hitherto, left the question unsettled; and pathology appears to have furnished proofs on both sides. Thus, where the right eye had been lost for a considerable time, the optic nerve of the *same* side has been found in a state of atrophy through its whole extent. In other cases of the kind, the posterior portion of the *left* nerve has been found in this condition.[1] Fishes have the nerve arising from one side of the brain, and passing to the eye of the other side; hence crossing, but not uniting. On the other hand, Vesalius[2] gives a plate of a case in which he found the optic nerves passing to the eye of the same side from which they originate, without touching at all; and yet without disturbance of vision. It is not necessary however, to adduce the numerous cases that have been published in favour of the one view or the other. It is impossible to sift those that are entitled to implicit confidence from those that are not. It may merely be remarked that certain observations of Valsalva, Cheselden,[3] and Petit[4] appear to show, that where the brain is injured, it is the eye of the opposite side that is affected; and, in cases of hemiplegia or paralysis of one side of the body, we certainly have many instances for testing the accuracy of this opinion. Sömmering[5]—whose correctness as an observing anatomist has never been disputed—affirms, that he had an opportunity of examining seven blind

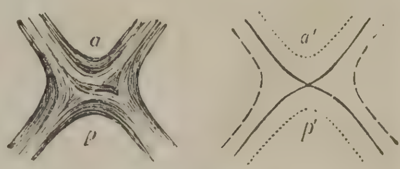
Fig. 288.



Optic Nerves, with the origin of seven other Pairs of Nerves.

1, 1. Globe of the eye; the one on the left hand is perfect, but that on the right has the sclerotic and choroid coats removed in order to show the retina. 2. Chiasm of the optic nerves. 3. Corpora albicautia. 4. Infundibulum. 5. Pons Varolii. 6. Medulla oblongata. 7. Third pair. 8. Fourth pair. 9. Fifth pair. 10. Sixth pair. 11. Seventh pair. 12. Eighth pair. 13. Ninth pair.

Fig. 289.



Course of Fibres in the Chiasma, as exhibited by tearing off the superficial bundles from a specimen hardened in spirit.

a. Anterior fibres, commissural between the two retinæ. *p.* Posterior fibres, commissural between the thalami. *a′*, *p′*. Diagram of the preceding.

[1] Rudolphi, Grundriss der Physiologie, B. ii. Abth. 1, S. 203, Berlin, 1823.
[2] De Corp. Human. Fabric., lib. iv. c. 4.
[3] Anatomy of the Human Body, 13th edit., Lond., 1792.
[4] Mémoir. de l'Acad., 1723 and 1728.
[5] Blumenbach, Med. Bibl., ii. 2, S. 368; and De Decussatione Nervorum Opticorum, Mogunt., 1786.

persons, in all of whom the atrophy of the nerve was on the side or root opposite to the eye affected.[1]

Some, again, have advanced an opinion, that the decussation is partial, and concerns only the internal filaments; that the other filaments pass directly on to half the corresponding eye; so that one-half of each eye is supplied by straight fibres proceeding directly from the root of the same side; the other half by those resulting from the decussation of the internal fibres. Messrs. Wollaston,[2] Bérard, Pravaz,[3] Gall and Spurzheim, Cuvier, Serres, Vicq-d'Azyr, Caldani, Ackermann, the brothers Wenzel, G. R. Treviranus, J. Müller, Ruete,[4] and others,[5] embrace this opinion for the purpose of explaining the anomaly of vision called *hemiopia*, in which only one-half the object is seen. MM. Cuvier, Serres, and Caldani assert, that they have noticed the above arrangement in the nerves of the horse, when subjected to appropriate maceration. Mr. H. Mayo[6] states that the optic nerve consists in man of three tracts; the innermost of which is wholly commissural, connecting the two retinæ anteriorly, and the optic ganglia posteriorly. The middle tract decussates, and is considered by him to supply the part of the retina that lies on the inner side of each eyeball, between its anterior border and the entrance of the optic nerve. The external tract, he affirms, does not decussate, but passes on to supply the outer portion of the retina of the same side. Hence, the right optic nerve, in Mr. Mayo's view, supplies the right side of each eyeball; and the left the left. Dr. Wollaston himself was affected with hemiopia; and, in his case, the loss of vision was sometimes on one side, and sometimes on the other; and he thought, that the phenomena might be explained by partial decussation of the optic nerves; but Messrs. Solly[7] and Mayo have known instances of a like affection involving alternately the centre and circumference of the retina, and therefore not attributable to any such structural arrangement.

These views are opposed, also, by the direct experiments of M. Magendie.[8] He divided, in a rabbit, the right optic nerve, behind the point of decussation, or what has been called the *chiasm* of the nerves:—the sight of the left eye was destroyed. On cutting the left root, the sight of the right eye was equally destroyed; and on dividing the bond of union, in another rabbit, by a longitudinal incision, made between the nerves, vision was entirely abolished in both eyes;—a result, which, as he properly remarks, proves not only the existence of decussation, but also that it is total, and not partial as Wollaston had supposed. Another experiment, which he instituted, led to a similar result. Fifteen days before examining a pigeon he destroyed one eye. The nerve

[1] A case elucidative of this point in Lallemand, Sur les Pertes Seminales; and in Dr. Wood's translation in Dunglison's American Med. Library for 1839, p. 30.

[2] Philosophical Transact., 1824, p. 222.

[3] Archives Générales de Médecine, Mai, 1825, p. 59.

[4] Wagner's Handwörterbuch der Physiologie, 16te Lief., S. 297, Braunschweig, 1847.

[5] Hildebrandt's Handbuch der Anatomie, von E. H. Weber, Band. iii. S. 438, Braunschweig, 1832; Blumenbach, op. citat.; Sir D. Brewster's Natural Magic, Amer. edit., p. 36, New York, 1833; and Pouillet, Élémens de Physique, iii. 338, Paris, 1832.

[6] London Medical Gazette, Nov. 5, 1841.

[7] The Human Brain, its Configuration, &c., p. 263, London, 1836; and Carpenter's Human Physiology, Amer. edit., p. 246, Philada., 1843.

[8] Précis, &c., edit. cit., i. 64.

of the same side, as far as the chiasm, was wasted; and, behind the chiasm, the root of the opposite side. MM. Rolando and Flourens,[1] too, found in their experiments, that when one cerebral hemisphere was removed, the sight of the opposite eye was lost. We may conclude, then, in the present state of our knowledge, that there is not simply a junction, or what the French call *adossement*, of the optic nerves; but that they decussate at the sella turcica.[2]

The eye proper receives numerous vessels,—*ciliary arteries* and *veins* —and several nervous ramifications,—*ciliary nerves*—the greater part of which proceed from the ophthalmic or lenticular ganglion. The following are the dimensions, &c., of the organ, on the authority of Petit, Young, Gordon, and Brewster.

			Eng. inch.
Length of the antero-posterior diameter of the eye,			0·91
Vertical chord of the cornea			0·45
Versed sine of the cornea			0·11
Horizontal chord of the cornea			0·47
Size of pupil seen through the cornea			0·27 to 0·13
Size of pupil diminished by magnifying power of cornea			0·25 to 0·12
Radius of the anterior surface of the crystalline			0·30
Radius of posterior surface			0·22
Principal focal distance of lens			1·73
Distance of the centre of the optic nerve from the *foramen centrale* of Sömmering			0·11
Distance of the iris from the cornea			0·10
Distance of the iris from the anterior surface of the crystalline			0·02
Field of vision above a horizontal line	50°	120°	
Field of vision below a horizontal line	70°		
Field of vision in a horizontal plane	150°[3]		
Diameter of the crystalline in a woman above fifty years of age			0·378
Diameter of the cornea			0·400
Thickness of the crystalline			0·172
Thickness of the cornea			0·042[4]

It is proper to remark, that all these measurements were necessarily taken on the dead organ, in which the parts are by no means in the same relative situation as when alive; and this is a cause why many of the phenomena of vision can never be determined with mathematical accuracy.

3. ACCESSORY ORGANS.

The visual organs being of an extremely delicate texture, it was of obvious importance, that they should be guarded against deranging influences. They are accordingly provided with numerous parts that afford them protection, and enable them to execute the functions for which they are destined. They are, in the first place, securely lodged in the bony cavities called *orbits*, which are of a conical figure, with the apices directed inwards. In the truncated apex the *foramen opticum* is situate, by which the optic nerve enters the orbit. Here are, also, *superior orbitar* and *spheno-maxillary fissures*, through which many

[1] Recherches Expérimentales sur le Système Nerveux, 2de édit., Paris, 1842.

[2] See, on this subject, Adelon, Physiologie de l'Homme, i. 402, 2de édit., Paris, 1829, and Bostock's Physiology, edit. cit., p. 709.

[3] According to Young, Philos. Transact., P. i. p. 46, Lond., 1801, the field of vision internally is 60°, externally 90°; according to Purkinje, (Rust's Magazin, B. xx. Berlin, 1825,) internally 60°, externally 100°.

[4] For the dimensions of different parts of the eye see Krause, in Meckel's Archiv für Anatomie und Physiologie für 1832; and Longet, Traité de Physiologie, ii. 41, Paris, 1850.

vessels and nerves proceed to the eye and its appendages. The base of the orbits is not directly opposite the apices, but tends outwards; so that the axes of these cavities, forming an angle of about 90° with each other, if prolonged, would meet at the sella turcica. The eye, however, is not placed in the direction of the axis of the orbit, but straight forward; and as it is nearly spherical, it is obvious that it cannot completely fill the conical cavity. In Fig. 290, muscles 9 and 13 indicate the shape of the upper and lower surfaces of the cavities;—the whole of the space between the posterior part of the orbit and the muscles, which is not occupied by the optic nerve, being occupied by an adipous areolar tissue, on which the eye is placed as it were on a cushion. Under special morbid circumstances, this deposit becomes greatly augmented, so as to cause the eye to start from its socket,—constituting the disease called *exophthalmos.*

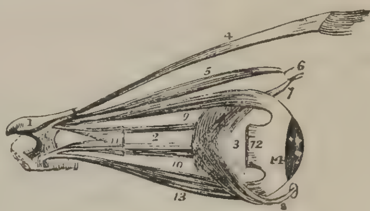
The parts, however, that are more immediately reckoned amongst the protectors of the organ—*tutamina oculi*—are the *eyebrows*, *eyelids*, and *lachrymal apparatus*. The *eyebrows* or *supercilia* are situate immediately on the *superciliary* ridge of the frontal bone. They consist of hair, varying in colour according to the individual, and turned towards the outer angle of the eye; of common integument; sebaceous follicles, situate at the root of each hair; and muscles to move them,—namely, the frontal portion of the occipito-frontalis, the upper edge of the orbicularis palpebrarum, and the corrugator supercilii. The *palpebræ* or *eyelids* are, in man, two in number, an upper and a lower, or a greater and a less,—*palpebra major* seu *superior*, and *palpebra minor* seu *inferior*,—the former covering three-fourths of the eye; hence the transverse diameter of the organ is not represented by their union,—the latter being much below it, and therefore improperly termed, by Haller, *æquator oculi*. By the separation of the eyelids, we judge, but inaccurately, of the size of the eye,—one, who is capable of separating them largely from each other, appearing to have a large eye;—and conversely.

The edge of the eyelids is thick, rounded, and furnished with hairs, which resemble generally, in colour, those of the head. These are the *eyelashes* or *cilia*. On the upper eyelid they are curved upwards; on the lower downwards. The eyelids are formed of four membranous layers in superposition; and of a fibro-cartilage, which extends along the whole edge, and keeps them tense. The outermost of these layers is the common integument, the skin of which is delicate and semitransparent, yielding readily to the motions of the eyelids, and having numerous transverse folds. The areolar tissue beneath the skin is very loose; and, under particular circumstances, is infiltrated by a serous fluid, which gives the eyelids, especially the lower, a dark appearance; but they never contain fat. Beneath the common integument is the muscular stratum, formed, in the lower eyelid, by the *orbicularis palpebrarum;* in the upper, by the same muscle, and the *levator palpebræ superioris*, (Fig. 290,) which arises from above the foramen opticum, and is inserted into the superior edge of the fibro-cartilage of the tarsus. Beneath the orbicularis palpebrarum, again, is a fibrous layer, which occupies the whole of the eyelids, passing from the edge of the orbit to the tarsal margin, and seeming intended to limit the motion of the eyelids, when they approximate each other. The last layer,

and that which forms the posterior surface of the eyelids, is a fine, delicate, transparent, mucous membrane, called *tunica conjunctiva* or *tunica adnata;* so named because it joins the eyelids to the globe of the eye. It lines, in fact, the eyelids, and is reflected over the ball; but it has been a matter of contention whether it passes over the transparent cornea. The generality of anatomists say it does; M. Ribes,[1] however, maintains the opinion, that it extends only as far as the circumference of the cornea, and that the cornea itself is covered by a proper membrane. Physiologically, this dispute is of no moment. At its outer surface, a humour is constantly exhaled, which keeps it moist, and facilitates the motions of the eyelids over the eyeball. Its loose state also favours these motions.

Both eyelids are kept tense by the aid of a fibro-cartilage, situate along the edge of each, and called *tarsus.* That of the upper is much more extensive than that of the lower; and both seem as if cut obliquely at the expense of their inner surface; so that, in the opinion of most anatomists, when the eyelids are brought together, a triangular canal is formed between them and the ball of the eye, which has been conceived useful in conducting the tears towards the lachrymal puncta. M. Magendie[2] denies that any such canal exists: and there seems little evidence of it, when we examine how the tarsal cartilages come in contact. Such a canal, destined for the purposes mentioned, would seem superfluous. Besides the eyelashes, certain compound glands or follicles, called *Meibomian*, are situate in the substance of the tarsal cartilages. They are thirty or forty in number in the upper eyelid; and twenty-five or thirty in the lower, are in particular furrows between the tarsal fibro-cartilages and the conjunctiva, and secrete a sebaceous fluid, called by the French *chassie*, when in the dry state; by the Germans, Augenbutter, ("eyebutter,") and by us, *gum of the eye.* It serves the purposes of follicular secretions in general.

Fig. 290.



Muscles of the Eyeball.

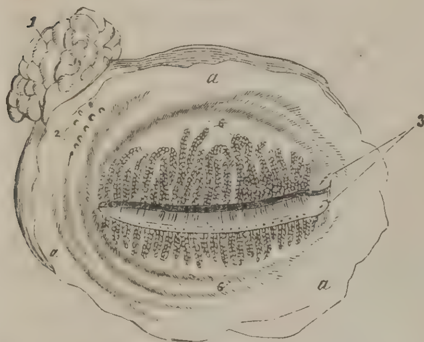
1. A small fragment of the sphenoid bone around entrance of optic nerve into orbit. 2. Optic nerve. 3. Globe of eye. 4. Levator palpebræ muscle. 5. Superior oblique muscle. 6. Its cartilaginous pulley. 7. Its reflected tendon. 8. Inferior oblique muscle; the small square knob at its commencement is a piece of its bony origin broken off. 9. Superior rectus. 10. Internal rectus almost concealed by optic nerve. 11. Part of external rectus, showing its two heads of origin. 12. Extremity of external rectus at its insertion; the intermediate portion of muscle having been removed. 13. Inferior rectus. 14. Tunica albuginea formed by expansion of tendons of four recti.

The arrangement of the eyelids differs in different animals. In several, both move; but, in others, only one; either the lower rising to join the upper, or the upper descending to meet the lower. In the sunfish—*tetraodon mola*—the eyelid is single and circular, with a perforation in the centre, which can be contracted or enlarged, according to circumstances. In many animals there is a third eyelid, called

[1] Mémoires de la Société Médicale d'Émulation, vol. vii., Paris, 1817.
[2] Précis Elémentaire, i. 52.

nictitating membrane, which is of a more delicate texture and more largely supplied with bloodvessels; and in some animals is transparent. In birds it exists, and is well seen in the owl. It is at the inner angle of the eye; and is capable of being drawn over the ball like a curtain by two special muscles, and of thus freeing the surface of the eye from extraneous substances. In man, it is only a vestige, destined to no apparent use. It is called *valvula* or *plica semilunaris*.

Fig. 291.

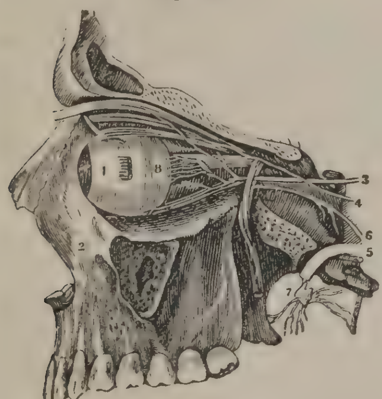


Meibomian Glands seen from the Inner or Ocular Surface of the Eyelids, with the Lachrymal Gland—of the Right Side.

a. Palpebral conjunctiva. 1. Lachrymal gland. 2. Openings of lachrymal ducts. 3. Lachrymal puncta. 6. Meibomian glands.

The eye has its proper muscles, capable of moving it in various directions. Their arrangement is readily understood. They are six in number:—four *recti* or *straight muscles;* and two *oblique*. 1. *Rectus superior* or *levator*. 2. *Rectus inferior* or *depressor*. 3. *Rectus internus* or *adductor;* and 4. *Rectus externus* or *abductor*. All arise from the base of the orbit, around the optic foramen; pass forward to vanish on the sclerotica; and, according to some anatomists, extend over, and form a layer to, the cornea.

Fig. 292.



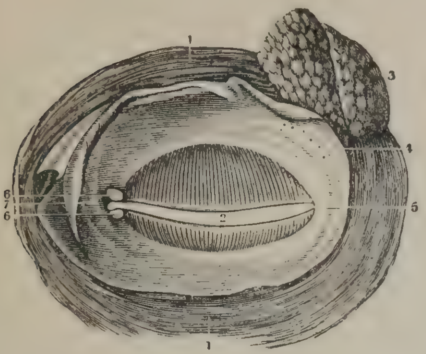
View of the Third, Fourth, and Sixth Pairs of Nerves.

1. Ball of the eye and rectus externus muscle. 2. Superior maxilla. 3. Third pair, distributed to all the muscles of the eye except the superior oblique and external rectus. 4. Fourth pair, going to the superior oblique muscle. 5. One of the branches of the seventh pair. 6. Sixth pair, distributed to the external rectus muscle. 7. Spheno-palatine ganglion and branches. 8. Ciliary nerves from the lenticular ganglion, the short root of which is seen to connect it with the third pair.

The *oblique muscles* are—1. *Greater oblique, obliquus superior, patheticus* or *trochlearis*, which arises from the inner side of the foramen opticum; passes forwards to the internal orbitar process of the frontal bone, where its tendon is reflected over a pulley or *trochlea*, and crosses the orbit to be inserted into the upper, posterior, and outer part of the globe of the eye. 2. *Lesser oblique* or *obliquus inferior*, whose fibres arise from the anterior and inner part of the floor of the orbit, near the lachrymal groove; pass under the eyeball, and are inserted between the entrance of the optic nerve and insertion of the abductor oculi, and opposite the insertion of the obliquus superior. These muscles have their proper nerves. The *third pair—mo-*

tores oculorum or *common oculo-muscular*—are distributed to all the muscles except the trochlearis and abductor; the *fourth pair* or *pathetic* or *internal oculo-muscular*, to the trochlearis singly; and the *sixth pair* or *external oculo-muscular*, to the abductor.

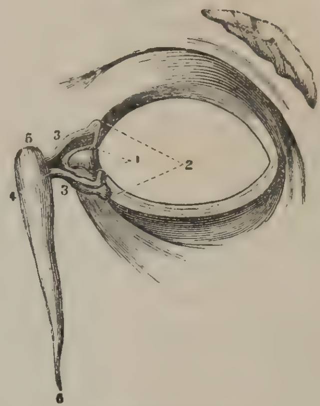
Fig. 293.



Posterior View of the Eyelids and Lachrymal Gland.

1, 1. Orbicularis palpebrarum muscle. 2. Borders of the lids. 3. Lachrymal gland. 4. Its ducts opening in the upper lid. 5. Conjunctiva covering the lids. 6. Puncta lacrymalia. 7. Lachrymal caruncle as seen from behind.

Fig. 294.



Lachrymal Canals.

1. Puncta lacrymalia. 2. Cul-de-sac at the orbital end of the canal. 3. Course of each canal to the saccus lacrymalis. 4, 5. Saccus lacrymalis. 6. Lower part of the ductus ad nasum.

The office of *tutamina oculi* is not wholly engrossed by the parts that have been mentioned. The apparatus for the secretion of the tears participates in it, by furnishing a fluid, which lubricates the surface of the eye, and keeps it in the necessary degree of humidity for the proper performance of its functions. It is a beautiful, and ingenious little apparatus; the structure of which can easily be made intelligible. It consists of the lachrymal gland; the excretory ducts of the gland; the caruncula lacrymalis; the lachrymal ducts; and the nasal duct; in other words, of two sets of parts,—one, forming the fluid and pouring it on the anterior surface of the eye; the other comprising the organs for its excretion. The *lachrymal gland* is situate in a small fossa or depression at the upper, anterior, and outer part of the orbit. It is an oval body of the size of a small almond; of a grayish colour; and composed of small, whitish, granular bodies collected into lobes. From these, six or seven excretory ducts arise, which run nearly parallel to each other, and open on the inner side of the upper eyelid, near the outer angle of the eye and the tarsal cartilage. Through these ducts, the *tears*, secreted by the lachrymal gland, are spread over the tunica conjunctiva. They are not secreted by animals that live in water.

At the inner angle of the eye is the *caruncula lacrymalis*. It is a collection of small mucous follicles, which secrete a thick, whitish humour, to fulfil a similar office with the secretion of the Meibomian follicles. It completes the circle formed by those follicles around the eyelids. The rosy or pale colour of the body is supposed to indicate strength or debility. This it does, like other vascular parts of the system, and in a similar manner. The *puncta lacrymalia* are two

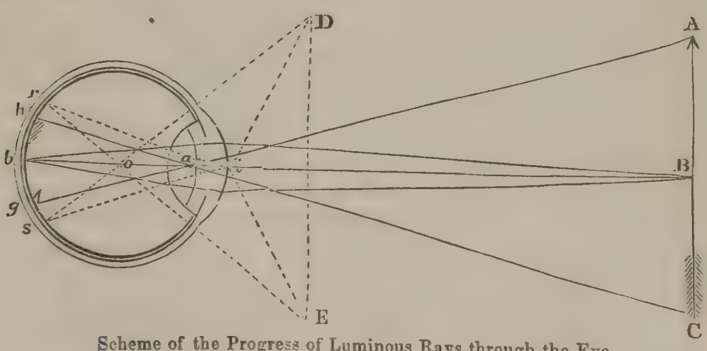
small orifices, situate near the inner angle of the eye; the one in the upper; the other in the lower eyelid, at the part where the eyelids quit the globe to pass round the caruncula lacrymalis. They are continually open, and directed towards the eye. Each punctum is the commencement of a *lachrymal duct*, which passes towards the nose in the substance of the eyelids, between the orbicularis palpebrarum and tunica conjunctiva. These open, as represented in Fig. 294, into the *lachrymal sac*, which is nothing more than the commencement of the *nasal duct* or *ductus ad nasum*. The bony canal is formed by the anterior half of the os unguis, and by the superior maxillary bone, and opens into the nose behind the os spongiosum inferius. Through these excretory ducts, all of which are lined by a prolongation of mucous membrane, the tears pass into the nasal fossæ.

Dr. Horner[1] has best described a small muscle, which is evidently a part of the lachrymal apparatus, and to which he gives the name *tensor tarsi*. It is on the orbital face of the lachrymal sac; arises from the superior posterior part of the os unguis; and, after having advanced a quarter of an inch, bifurcates; one fork being inserted along each lachrymal duct, and terminating at or near the punctum. It is probable, that the function of this muscle is to keep the punctum properly directed towards the eyeball; or, as Dr. Physick suggested, to keep the lids in contact with the globe. The office, assigned to it by Dr. Horner, of enlarging, by its contraction, the cavity of the lachrymal sac, and thus producing a tendency to a vacuum—which vacuum can be more readily filled through the puncta than through the nose, owing to the valves or folds of the internal membrane of the sac—is ingenious, but apocryphal. The tensor tarsi muscle is now commonly associated with the name of Horner[2]—"*muscle of Horner*."[3]

4. PHYSIOLOGY OF VISION.

The preceding anatomical sketch will enable the reader to comprehend this important organ in action. In describing the office executed

Fig. 295.



Scheme of the Progress of Luminous Rays through the Eye.

[1] Lessons in Practical Anatomy, 3d edit., p. 116, Philad., 1836; and General Anatomy and Histology, 8th edit., ii. 394, Philad., 1851. Also, Rosenmüller's Handbuch der Anatomie, dritte Auflage, Leipz., 1819.

[2] T. W. Jones, art. Lachrymal Organs, Cyclop. of Anat. and Physiol., July, 1840.

[3] See M. Sappey, Researches on the shape, size and weight of the globe of the eye, in Mémoires de la Société de Biologie, année 1854, p. 231, Paris, 1855.

by its various components, we shall follow the order there observed, premising some general considerations on the mechanism of vision; and afterwards depict the protecting and modifying influences exerted by the various accessory parts:—the different phenomena of vision will next be explained; and, lastly, the information conveyed to the mind by this sense.

In tracing the progress of luminous rays through the purely physical part of the organ, we shall, in the first instance, suppose a single cone to proceed from a radiant point in the direction of the axis of the eye; or, in other words, of the antero-posterior diameter of the organ, B *b*.

It is obvious, that the rays which fall upon the transparent cornea can alone be inservient to vision. Those that impinge upon the sclerotica are reflected; as well as a part of those that fall upon the cornea, giving occasion, in the latter case, to the image observed in the eye, and to the brilliancy of the organ. Nor does the whole of the cornea admit rays, for it is commonly more or less covered, above and below, by the free edge of the eyelids. Again: the whole of the light, that enters the cornea, does not impinge upon the retina. A portion falls upon the iris, and is reflected back to the eye, in such manner as to give us the notion of the colour of the organ. It is, consequently, the light, which passes through the pupil, that can alone attain the retina.

Some interesting points of diagnosis are connected with the reflection which takes place from the humours of the eye. If a lighted candle be held before an eye the pupil of which has been dilated by belladonna, and in which there is no obscurity in the humours or their capsules, three distinct images of the flame are perceptible—situated one behind the other. Of these images the anterior and the posterior are erect; the middle inverted. The anterior is the brightest and most distinct; the posterior the least so. The middle one is the smallest, but it is bright. The anterior erect image is produced by the cornea; the posterior by the anterior surface of the lens; and the middle or inverted image by the concave surface of the capsule of the crystalline. M. Sanson proposed this catoptric method of examining the eye as a means of diagnosis between cataract and amaurosis,—in the latter all the images being seen; and experience has shown it to be a valuable mode of investigating various conditions of the eye, which might not be readily understood without its agency.[1]

If we suppose a luminous cone to proceed from a radiant point B, Fig. 295, directly in the prolongation of the antero-posterior diameter of the eye, the axis of this cone will also be the axis of the organ; so that a ray of light, impinging upon the humours in the direction of the axis, as in the case of the lenses previously referred to, will pass through the humours without undergoing deflection, and will fall upon the retina at *b*. This, however, is not the case with the other rays composing the cone. They do not fall perpendicularly upon the cornea; and are,

[1] Gazette Médicale de Paris, 27 Janvier, 1844. See, also, T. Wharton Jones, The Principles and Practice of Ophthalmic Medicine and Surgery, Amer. edit., p. 39, Philad., 1847; Lawrence, Treatise on Diseases of the Eye, Amer. edit., by Dr. Hays, p. 93, Philad., 1854; and Mackenzie, Practical Treatise on Diseases of the Eye, Amer. edit., by Dr. A. Hewson, p. 705, Philad., 1855.

consequently, variously refracted in their passage through the cornea, aqueous humour, crystalline, and vitreous humour; but in such a manner that they join their axis in a focus at a point where it strikes the retina.

The transparent parts of the eye, as has been seen, are of different densities, and consequently possessed of different refractive powers. These powers it has been attempted to estimate; and the following is the result of the slightly discordant evaluations of different experimenters;—the power of air being 1·000295.

	Cornea.	Aqueous Humour.	CRYSTALLINE LENS.				Vitreous Humour.
			Capsule.	Outer Layers.	Centre.	Mean.	
Hawksbee . .		1·33595					1·33595
Jurin		1·3333					
Rochon . . .		1·329					1·332
Young . . .		1·3333					
Chossat . . .	1·339	1·338	1·339	1·338	1·393	1·384	1·339
Brewster . .		1·3366	1·3767		1·3990	1·3839	1·3394[1]

A ray of light impinging obliquely on the surface of the transparent cornea passes from a rarer to a denser medium. It will, consequently, be refracted towards a perpendicular raised from the point of impact. From this cause, as well as from the convexity of the cornea, it will be rendered more convergent; or, in other words, approach the axis of the cone. In proceeding through the aqueous humour, little variation will be produced, as the densities of it and the cornea differ but little; the latter is slightly more refractive, according to the table; and therefore the tendency will be to render the ray less convergent. This convergence gives occasion to the passage of a greater number of rays through the pupil; and necessarily adds to the intensity of the light that impinges on the crystalline. Pursuing the ray through the two chambers of the eye, we find it next impinging on the surface of the crystalline, which possesses a much higher refractive power than the cornea or aqueous humour; in the ratio of 1·384 to 1·336. From this cause, and from the convexity of the anterior surface of the lens, the ray is rendered still more convergent or approaches still more the axis of the cone. It is probable, however, that even here some of the light is reflected back; and goes towards the formation of the image in the eye, and the brilliancy of the organ; other reflected rays perhaps impinge upon the pigmentum nigrum lining the posterior surface of the iris, and are absorbed by it. From the crystalline the ray emerges into a medium possessing less refractive power; and, therefore, it is deflected from the perpendicular. The shape, however, of the posterior surface of the lens so modifies the perpendiculars, as to occasion such a degree of convergence, that the oblique ray meets the axis at a focus on the retina. (See Figs. 261 and 295.) In this manner two cones are formed; one having its apex at the radiant point, and its base on the

[1] For the measurements of M. Vallée, see his Théorie de l'Œil, p. 20, Paris, 1843; or Longet, Traité de Physiologie, ii. 42, Paris, 1850.

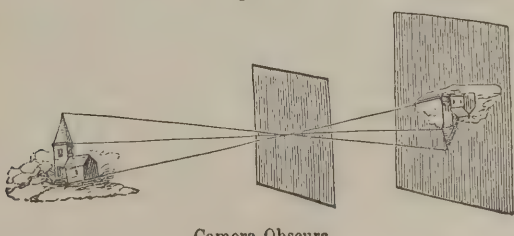
cornea—the *objective cone;*—the other having its apex on the retina, and termed the *ocular cone.*

These remarks apply chiefly to the cone proceeding in the direction of the axis of the different humours, from a single radiant point. It is easy to understand, that every portion of the object A B C, Fig. 295, must be a radiant point, and project so many cones in an analogous manner, which, by impinging upon the retina, form a picture of the object upon that expansion, at *g b h.* It is important, however, to observe, that the rays proceeding from the upper part of the object fall, after refraction, upon the lower part of the retina; and those from the lower part of the object upon the upper; so that the picture or representation of the object on the retina must be inverted. How the idea of an erect object is excited in the mind will be the subject of after inquiry.

When rays, as A *g* and C *h*, fall obliquely on a lens, and pass through its centre, they suffer refraction at each of its surfaces; but as the two refractions are equal, and in opposite directions, they may be esteemed to pursue their course in a straight line. The point *a*, at which these various rays cross, is called the *optic centre* of the crystalline. Each of the straight rays proceeding from a radiant point may be assumed as the axis of all the rays proceeding obliquely from the same point; and the common focus must fall on some part of this axis. In this way the object is represented in miniature, and inverted, on the retina. As, however, the oblique ray has to pass through the cornea and aqueous humour, before it impinges on the crystalline, it undergoes considerable deflection; and consequently it is not accurate to represent it as pursuing a straight course through the different humours on its way to the retina. The main deflection—as in the case of the rays D *t s*, and E *t r*, Fig. 295—occurs at the entrance of the rays into the cornea.

That an inverted representation of external objects is formed within the eye is in accordance with sound theory; and is supported not only by indirect, but by direct experiment. If a double convex lens be fitted into an opening made in the window-shutter of a darkened chamber, luminous cones will proceed from the different objects on the outside of the house, and converge within; so that if they be received on a sheet of paper, a beautiful and distinct image of the object will be

Fig. 296.



Camera Obscura.

apparent. This is the well-known instrument, the *camera obscura*, of which the organ of sight may be regarded as a modification. Making abstraction, indeed, of the cornea, and of the aqueous and vitreous

humours, the representation of the eye in Fig. 295, with the object, A B C and its image on the retina, is the common camera obscura. The eye is, therefore, more complicated and more perfect than this simple instrument: the cornea, with the aqueous and vitreous humours, is added for the purpose of concentrating the light on the retina; the latter, in addition, affording a large space for the expansion of the retina, and preventing the organ from collapsing. In the operation for cataract by extraction, which consists in removing the lens through an opening made in the lower part of the cornea, the aqueous humour escapes, but is subsequently regenerated. If, however, too much pressure be exerted on the ball, to force the crystalline through the pupil and the opening in the cornea, the vitreous humour is sometimes pressed out, when the eye collapses, and is irretrievably lost.

Experiments have been instituted on this subject, the results of which are even more satisfactory than the facts just mentioned. These have been of different kinds. Some experimenters have formed artificial eyes of glass, to represent the cornea and crystalline, with water in place of the aqueous and vitreous humours. Another mode has been to place the eye of an ox or a sheep in a hole in the shutter of a dark chamber, having previously removed the posterior part of the sclerotica so as to permit the images of objects on the retina to be distinctly seen. Malpighi and Haller employed a more easy method. They selected the eyes of the rabbit, pigeon, puppy, &c., the choroid of which is nearly transparent; and, directing the cornea towards luminous objects, they saw them distinctly depicted on the retina. M. Magendie[1] repeated these experiments by employing the eyes of albino animals, as those of the white rabbit, white pigeon, white mouse, &c., which afford great facilities,—the sclerotica being thin, and almost transparent; the choroid, also, thin, and when the blood, which gives it colour, has disappeared after the death of the animal, offering no sensible obstacle to the passage of light. In every one of these experiments, external objects were found to be represented on the natural or artificial retina in an inverted position; the image being clearly defined, and with all the colours of the original. Yet how minute must these representations be in the living eye; and how accurate the mental appreciation,—seeing, that each impression from myriads of luminous points is transmitted by the retina to the encephalon, and perceived with unerring certainty!

In the prosecution of his experiments—in some of which he was assisted by M. Biot—M. Magendie found, as might have been expected, that any alteration in the relative proportion or situation of the different humours had a manifest effect upon vision. When a minute opening was made in the transparent cornea, and a small quantity of the aqueous humour permitted to escape, the image had no longer the same distinctness. The same thing occurred when a little of the vitreous humour was discharged by a small incision made through the sclerotica. He farther found, that the size of the image on the retina was proportionate to the distance of the object from the eye. When the whole of the aqueous humour was evacuated, the image seemed to

[1] Précis Elémentaire, i. 70.

occupy a greater space on the retina, and to be less distinct and luminous; and the removal of the cornea was attended with similar results. When the crystalline was either depressed or extracted, as in the operation for cataract, the image was still formed at the bottom of the eye; but it was badly defined; slightly illuminated, and at least four times the usual size. Lastly,—when the cornea, aqueous humour, and crystalline were removed, leaving only the capsule of the crystalline and the vitreous humour, an image was no longer formed upon the retina: the light from the luminous body reached it, but it assumed no shape similar to that of the body from which it emanated.

Most of the results—as M. Magendie[1] remarks—accord well with the theory of vision. Not so, the distinctness of the image under these deranging circumstances. According to the commonly received notions on this subject, it is necessary, in order to have the object depicted with distinctness on the retina, that the eye should accommodate itself to the distance at which the object is placed. This is a subject, however, that will be discussed presently.

Such are the general considerations relating to the progress of luminous rays from an object through the dioptrical part of the organ of sight to the nervous portion—the retina. We shall now inquire into the offices executed by such of the separate parts that enter into its composition as have not already engaged attention.

We have shown, that the *cornea*, *aqueous humour*, *crystalline*, and *vitreous humour*, are a series of refractive bodies, to concentrate the luminous rays on the retina; to keep the parietes of the eye distended; and to afford surface for the expansion of the retina;—thus enlarging the field of vision. It is probably owing to their different refractive powers, that the eye is achromatic; or, in other words, that the rays, impinging upon the retina, are not decomposed into their constituent colours,—an inconvenience which appertains to the common lens (page 57). The eye is strictly achromatic; and it has been an object of earnest inquiry amongst philosophers to determine how the *aberration of refrangibility* is corrected in it. Euler,[2] first perhaps, asserted, that it is owing to the different refractive powers of the humours; and he conceived, that, by imitating this structure in the fabrication of lenses, they might be rendered achromatic. Experience has shown the accuracy of this opinion (Fig. 265). Others have believed, that the effect is produced by certain of the humours—as the aqueous and vitreous—which they have considered capable of correcting the dispersion produced by the cornea and crystalline. Others have placed it in the crystalline, the layers of which being of different dispersive powers may correct each other; whilst others, again, have ascribed it to the iris acting as a diaphragm, and thus preventing the rays of light from falling near the margin of the lens.[3] Lastly;—some have denied altogether the necessity for the eye's being achromatic; asserting, that the depth of the organ is so inconsiderable, that the dispersion of the rays,

[1] Précis Élémentaire, i. 73.

[2] Mem. Berlin, p. 279, pour 1747; and Letters of Euler, by Sir D. Brewster, Amer. edit., i. 163, New York, 1833.

[3] M. De Haldat, Optique Oculaire, suivi d'un Essai sur l'Achromatisme de l'Œil, p. 79, Paris et Nancy, 1849.

by the time they reach the retina, ought to be inappreciable. This was the opinion of M. D'Alembert. Dr. Maskelyne[1] calculated the amount of the aberration, that must necessarily take place in the eye, and concluded that it would be fourteen or fifteen times less than in a common refracting telescope; and therefore imperceptible. Uncertainty still rests on this subject; and it cannot be removed until the dispersive and refractive powers of the transparent parts of the organ as well as their exact curvatures shall have been mathematically determined. It has been already shown, that the data we possess on this subject from different observers are sufficiently imprecise.

Our knowledge, then, is restricted to the fact, that the eye is perfectly achromatic; and that, in this respect, it exceeds any instrument of human construction. The views of Euler are the most probable; and the effect is doubtless much aided by the iris or diaphragm, which prevents the rays from falling upon the margins of the lens, where, by the surfaces meeting at an angle, the aberration must necessarily be greatest.

Of the *coats of the eye*,—the *sclerotic* gives form to, and protects the organ.

The *choroid* is chiefly useful by the black pigment, which lines and penetrates it. It will be seen that some individuals, on insufficient grounds, have esteemed it the seat of vision. Leaving this question for the moment, and granting, as we shall endeavour to establish, that the impression is received upon the expansion of the optic nerve—the retina,—the use of the choroid would seem to be, in ordinary circumstances, to afford surface for the *pigmentum nigrum*, whose function it is to absorb the rays after they have passed through the retina; and thus to obviate the confusion, that would arise from varied reflections, were the choroid devoid of such dark covering. In *albinos* or white animals, in which the pigment is wanting, this inconvenience is really experienced; so that they become *nyctalopes*, or, at least, see but imperfectly during the day. In the night, or when the light is feeble, their vision is unimpaired; hence the albinos of our species have been called by the Germans and Dutch, Kakerlaken or *cockroaches*. Sir Everard Home[2] is of opinion, that the pigmentum nigrum is provided as a defence against strong light; and that, hence, it is lightest in those countries least exposed to the scorching effects of the sun. In confirmation of this, he remarks, that it is dark in the monkey, and in all animals that look upwards, and in all birds exposed to the sun's rays; whilst the owl, that never sees the sun, has no black pigment. It doubtless possesses the function assigned to it by Sir Everard.

The use of the shining spot on the outside of the optic nerves of quadrupeds, called *tapetum*, has been an interesting theme of speculation; and has given rise to much ingenious, and to not a little ridiculous, hypothesis amongst naturalists. The absence of the black pigment necessarily occasions the reflection of a portion of the rays from the membrana Ruyschiana; and it has been presumed, that these

[1] Philosophical Transactions for 1789, lxix. 256.
[2] Lectures on Comparative Anatomy, iii. 220, Lond., 1823.

reflected rays, in their passage back through the retina, may cause a double impression, and thus add to the intensity of vision. Another view has been, that the reflected rays may pass outwards through the retina without exciting any action, to be thrown on the object in order to increase the distinctness of the image on the retina, by an increase of its light. Dr. Fleming,[1] who usually exhibits much philosophical acumen, and physiological accuracy, thinks it not probable, that both surfaces of the retina are equally adapted for receiving impressions of external objects, and is of opinion, that the rays, in their passage inwards, alone produce the image. M. Desmoulins[2] has, however, adduced many facts and arguments to show, that the tapetum really does act the part of a mirror; and, by returning the rays through the retina, subjects it to a double contact. He affirms, that in nocturnal animals, and in many fishes and birds, which require certain advantages to compensate for the conditions of the media in which they are situate, the tapetum is of great extent, and always corresponds to the polar segment of the eyeball or to the visual axis;—that in many animals, as in the cat, the pigment is wholly wanting; and that it is only necessary for the vision of diurnal animals. He farther remarks, that, in man, it diminishes according to age, and in advanced life becomes white; and he ingeniously presumes, that this is a means employed by nature to compensate, in some measure, for the gradual diminution of the sensibility of the retina,—the choroid beneath reflecting more and more of the rays in proportion as the pigment is removed from its surface.

The views of M. Desmoulins are the most satisfactory of any that have been propounded, and they are corroborated by the experiments of Gruithuisen, Esser, and Tiedemann,[3] which show, that the luminous phenomena never occur in the eyes of nocturnal animals when light is totally excluded. Gruithuisen observed it in the dead as well as the living animal. Tiedemann perceived it in a cat, which had been decapitated for twenty hours; and it did not cease until the humours had become turbid. The views of these observers impress us the more forcibly, when we compare them with certain fanciful speculations,—as that of M. Richerand,[4] who supposes, that the use of the tapetum is to cause animals to have an exaggerated opinion of *man!* As if the same exaggerated opinion would not be produced whatever were the object that impressed the organ.

The *iris* has been compared, more than once, to the diaphragm of a lens or telescope. Its function consequently must be,—to correct the *aberration of sphericity*, which would otherwise take place. This it does by diminishing the surface of the lens on which the rays impinge, so that they meet at the same focus on the retina. M. Biot has remarked, that this diaphragm is situate in the eye precisely at the place where it can best fulfil the office, and yet admit the greatest possible quantity of light.

[1] Philosophy of Zoology, i. 192, Edinb., 1822.
[2] Magendie's Journal de Physiologie, iv. 89.
[3] Traité Complet de Physiologie de l'Homme, &c., traduit par A. J. L. Jourdan, p. 550.
[4] Adelon, Physiologie de l'Homme, 2de édit., i. 443. See, also, Sir E. Home's Lectures on Comp. Anat., iii. 243.

The iris is capable of contracting or dilating, so as to contract or dilate the pupil. It has been already observed, that the views of anatomists regarding the muscular structure of the iris have been discrepant; and that some esteem it to be essentially vascular and nervous, the vessels and nerves being distributed on an erectile tissue. The partisans of each opinion explain the motions of the iris differently. They who admit it to consist of muscular fibres affirm, that the pupil is contracted by the action of the circular fibres, and dilated by that of the radiated. Those, again, that deny the muscularity of the organ say, that contraction of the pupil is caused by the afflux of blood into the vessels, or by a sort of turgescence similar to what occurs in erectile parts in general; and dilatation, by the withdrawal of the surplus fluid.

Admitting—and this must now be conceded—that the iris is really muscular, we meet with the singular anomaly in its physiology—that no ordinary stimulus, applied directly to it, has any effect in exciting it to contraction. It may be pricked with the point of a cataract needle without the slightest motion being excited; and, from the experiments of Fontana[1] and Caldani,[2] it seems equally insensible when luminous rays are made to impinge upon it; yet MM. Fowler, Rinhold, and Nysten[3] have proved, that it contracts like other muscular parts on the application of the galvanic stimulus. Like them, too, it is under the nervous influence,—its movements being generally involuntary; but, there is some reason to believe, occasionally voluntary. Dr. Roget asserts, that this is the case with his own eye.[4] In the parrot, and certain nocturnal birds, its motions are manifestly influenced by volition;[5] and when the cat is roused to attention, the pupil dilates, so as to allow a greater quantity of light to reach the retina. M. Magendie[6] affirms, that the attention and effort required to see minute objects distinctly occasion contraction of the human pupil. He selected an individual whose pupil was very movable; and placing a sheet of paper in a fixed direction as regarded the eye and light, he marked the state of the pupil. He then directed the person to endeavour, without moving the head or eyes, to read very minute characters traced on the paper. The pupil immediately contracted, and continued so, as long as the effort was maintained.

Many experiments have been made to discover the nerve, which presides over the movements of the iris. These experiments have demonstrated, that if, instead of directing a pencil of rays upon the iris, we throw it on the retina, or through the retina on the choroid, contraction of the pupil is immediately induced. The movements of the iris must, then, be to a certain extent under the influence of the optic as an afferent nerve. It is found, indeed, that if the optic nerve be divided on a living animal, the pupil becomes immovable and expanded. Yet, that the motions of the iris are not solely influenced by this nerve is evinced by the fact, that in many cases of complete

[1] Dei Moti dell' Iride, cap. i. p. 7, Lucca, 1765.
[2] Institutiones Physiologicæ, &c., Lips., 1785.
[3] Magendie, Ibid., i. 75.
[4] Outlines of Physiology, Amer. edit., by the Author, p. 286, Philad., 1839.
[5] Mayo, Outlines of Physiology, 4th edit., p. 286, Lond., 1837.
[6] Précis Elémentaire, 2de édit., i. 74.

amaurosis of both eyes, there has been the freest dilatation and contraction of the pupil; and also, that section of the nerve of the fifth pair, which chiefly supplies the iris, equally induces immobility of the pupil. The same effect is produced, according to Mr. Mayo,[1] by dividing the third pair. If the trunk of that nerve be irritated, contraction of the pupil is seen to follow; and, according to Desmoulins,[2] in the eagle, whose iris is extremely movable, the third is the only nerve distributed to the organ. The general remark, made by M. Broussais[3] on the organs that combine voluntary and involuntary functions, has been considered applicable here;—that they will be found to possess both cerebral and ganglionic nerves. Accordingly, M. Magendie[4] conjectures, that those of the ciliary nerves, which proceed from the ophthalmic ganglion, preside over the dilatation of the pupil, or are the nerves of involuntary action; and that those which arise from the nasal branch of the fifth pair preside over its contraction. We might thus understand why, in apoplexy, epilepsy, &c., the pupil should be immovably dilated. All volition and every cerebral phenomenon are abolished by the attack: the nerve of the fifth pair, therefore, loses its influence; and the iris is given up to the agency of the ganglionic nerves or nerves of involuntary action proceeding from the ophthalmic ganglion.

On the whole, our notions regarding the motions of the iris, and the nerves that preside over them, must be esteemed vague and unsatisfactory; and the obscurity is not diminished by a remark of Bellingeri.[5] The iris, he observes, derives its nerves from the ophthalmic ganglion, which is formed by the fifth in conjunction with the third pair; and its involuntary motions, he thinks, are regulated by the fifth pair. In those instances, in which the motions of the iris have been found dependent on the will, Bellingeri argues, that the ciliary nerves received no branches from the fifth—a fact, which has been proved by dissection, as well as by the circumstance, that in the parrot, owl, and the ray genus among fishes, in which the iris is under the will of the animal—there is no ophthalmic ganglion. The most recent, and most probable view is, that the annular fibres contract, so as to diminish the size of the pupil under the influence of the third pair; whilst the contraction of the radiating fibres and consequent dilatation of the pupil is under the cervical portion of the great sympathetic. Messrs. Budge and Waller[6] found, that such contraction was induced by irritating the nerve in the neck by the magneto-electric apparatus; whilst a permanent contraction of the pupil was induced by a division of the nerve,—the action of the third pair being no longer antagonized.

The iris contracts or dilates according to the intensity of the light that strikes the eye. If the light from an object be feeble, the pupil

[1] Commentaries, P. ii. p. 5, and Outlines of Human Physiology, &c., 4th edit., p. 287, Lond., 1837.

[2] Anatom. des Systèm. Nerveux, Paris, 1825.

[3] Traité de Physiologie appliquée à la Pathologie, translated by Drs. Bell and La Roche, 3d edit., p. 77, Philad. 1833.

[4] Précis, &c., ed. cit., i. 77.

[5] Dissert. Inaugural. Turin, 1823; cited in Edinb. Med. and Surg. Journal for July, 1834.

[6] Memoranda der Speciellen Physiologie des Menschen, S. 265, Weimar, 1853.

is dilated to admit more of the luminous rays: on the contrary, if the light be powerful, it contracts. We see this very manifestly on opening the eyes, after they have been for some time closed, and bringing a candle suddenly near them. It is one of the means frequently employed in cerebral disease to judge of the degree of insensibility.

We shall presently inquire into the effect of contraction or dilatation of the pupil on distinct vision; and show, that they are actions for accommodating the eye to vision at different distances.

We may conclude, then, that the iris is one of the most important parts of the visual apparatus; that its functions are multiple:—that it is partly the cause of the achromatism of the organ, by preventing the rays of greatest divergence from falling near the marginal parts of the crystalline;—that it corrects the aberration of sphericity; regulates the quantity of light admitted through the pupil, and accommodates the eye, to a certain extent, to vision at different distances.

An enumeration of the multiform sentiments regarding the functions of the *ciliary processes* will show how little we know, that is precise, on this matter also. They have often been considered contractile; some believing them connected with the motions of the iris, others to vary the distance of the crystalline from the retina. Jacobson[1] makes them dilate the apertures, which he conceives to exist in the *canal godronné*, so as to cause the admission of a portion of the aqueous humour into the canal; and thus to change the situation of the crystalline. Others believe, that they secrete the pigmentum nigrum; and others—the aqueous humour. But the processes are wanting in animals, in which the humours, notwithstanding, exist; and in our ignorance of their precise function, it has been considered that there is no opinion, perhaps, more probable than that of Haller;[2] that they are destined to assist mechanically in the constitution of the eye; and have no farther use.

The function of the *retina* remains to be considered. It is the part that receives the impression from the luminous rays, which impression is conveyed by the optic nerve to the brain. It was, at one time, universally believed to be the most delicately sensible membrane of the frame. It has been shown by the experiments of M. Magendie,[3] that the sensibility of both it and the optic nerve is almost entirely *special*, and limited to the appreciation of light;—that the *general* sensibility is exclusively possessed by the fifth encephalic pair; and that the nerve of special sensibility is incapable of executing its functions, unless that of general sensibility is in a state of integrity. That distinguished physiologist found, when a couching needle was passed into the eye at its posterior part, that the retina might be punctured and lacerated without the animal exhibiting evidences of pain. The same result attended his experiments on the optic nerves. These nerves, both anterior and posterior to their decussation, as well as the thalami nervorum opticorum, the superficial layer of the tubercula quadrigemina, and the three pairs of motor nerves of the eye, gave no signs of general sensibility. On the other hand, the general sensi-

[1] Magendie, Précis, edit. cit., i. 78.
[2] Element. Physiol., xvi. 4, 20.
[3] Op. cit., i. 83.

bility of the conjunctiva is well known. It is such, that the smallest particle of even the softest substance excites intense irritation. This general sensibility M. Magendie[1] found to be totally annihilated by the division of the fifth pair of nerves within the cranium; after which, hard-pointed bodies and even liquid ammonia made no painful impression on the conjunctiva. Nictation was arrested; and the eye remained dry and fixed like an artificial eye behind the paralysed eyelids. The sight, in this case also, was almost wholly lost; but by making the eye pass rapidly from obscurity into the vivid light of the sun, the eyelids approximated; and, consequently, slight sensibility to light remained; but it was slight.

In this sense, then, as in the senses of hearing and smell, we have the distinction between a special nerve of sense, and one of general sensibility: without the latter, the former is incapable of executing its elevated functions.

The expansion of the retina occupies at least two-thirds of the circumference of the eyeball. It is of obvious importance, that it should have as much space as possible; and, in certain animals, in which the sense is very acute, the membrane is plaited so as to have a much larger surface than the interior of the eyeball; and thus to allow the same luminous ray to impinge upon more than one point of the membrane. This is seen in the eyes of the eagle and vulture, and in nocturnal animals. The inconceivable acuteness of the sense of sight in birds of prey has been already referred to under the sense of smell. It was then stated, that the strange facts regarding the condor, vulture, turkey-buzzard, &c., which meet in numbers in the forest, when an animal is killed, ought rather, perhaps, to be referred to acuteness of the sense of sight than of smell. Sir Everard Home[2] affords an additional illustration of this subject. In the year 1778, Mr. Baber, and several other gentlemen were on a hunting party in the island of Cassimbusar, in Bengal, about fifteen miles north of the city of Marshedabad: they killed a wild hog of uncommon size, and left it on the ground near the tent. An hour after, walking near the spot where it lay, the sky being perfectly clear, a dark spot in the air, at a great distance, attracted their attention; it appeared to increase in size, and move directly towards them; as it advanced it proved to be a vulture flying in a direct line to the dead hog. In an hour, seventy others came in all directions, which induced Mr. Baber to remark,—"this cannot be smell!"

How inconceivably sensible to its special irritant must this membrane be in the human eye, when we consider that every part of an extensive landscape is depicted upon its minute surface; not only in its proper situation, but with all its varied tints; and how impracticable for us to comprehend, how the infinitely wider range of country can be so vividly depicted on the diminutive eye of the vulture, as to enable it to see its prey from such remote distances.

If pressure be made on the eyeball, behind the cornea, so as to affect the retina, concentric luminous circles are seen, opposite to the part on

[1] Op. cit., i. 494.
[2] Lectures on Comparative Anatomy, Lond., 1814–1828.

which the pressure is applied; and, if the pressure be continued for twenty or thirty seconds, a broad undefined light, which increases in intensity every moment, rises immediately before the eye. If the eyelids be open, and light be present—on the repetition of the last experiment, a dense cloud arises, instead of the broad undefined light; and the eye becomes, in a few seconds, perfectly blind; but in the course of three or four seconds after the finger is removed, the cloud appears to roll away from before the eye. From this, it seems, that sensations of light may be produced by mechanical pressure made on the retina; in other words, the retina becomes phosphorescent by pressure. The same thing is observed if a sudden blow be given on the eye, or if we place a piece of zinc under the upper lip, and a piece of copper above the eye. A flash of light is seen; produced, doubtless, by the galvanic fluid impressing directly, or indirectly, the optic nerve. The same thing occurs in the act of sneezing, and in forcing air violently through the nostrils. On repeating the experiment of pressing the eyeball, Sir David Brewster[1] observed, that when a gentle pressure is first applied, so as to compress slightly the fine pulpy substance of the retina, a circular spot of colourless light is produced, though the eye be in total darkness, and has not been exposed to light for many hours; but if light be now admitted to the eye, the compressed part of the retina is found to be more sensible to the light than any other part; and, consequently, it appears more luminous. If the pressure be increased beyond the point mentioned above, the circular spot of light gradually becomes darker, and, at length, black, and is surrounded with a bright ring of light. By augmenting the pressure still more, a luminous spot appears in the middle of the central dark one, and another luminous spot diametrically opposite, and beneath the point of pressure. "Considering the eye," says Sir David, "as an elastic sphere, filled with incompressible fluids, it is obvious, that a ring of fluids will rise round the point depressed by the finger; and that the eyeball will protrude all round the point of pressure; and consequently the retina, at the protruded part, will be *compressed* by the outward pressure of the contained fluid, while the retina on each side,—that is, under the point of pressure, and beyond the protruded part,—will be drawn towards the protruded part or be *dilated*. Hence the part under the finger, which was originally compressed, is now *dilated*, the adjacent parts are *compressed*, and the more remote parts, immediately without this, dilated also." "Now," continues Sir David, "we have observed, that when the eye is, under these circumstances, exposed to light, there is a bright luminous circle shading off externally and internally into total darkness. We are led therefore to the important conclusions, that when the retina is compressed in total darkness it gives out light; that when it is compressed, when exposed to light, its sensibility to light is increased; and that when it is dilated under exposure to light, it becomes absolutely blind or insensible to all luminous impressions."

Having traced the mode in which the general physiology of vision is effected, and the part performed by each of the constituents of the eye proper, we shall briefly consider the functions of the rest of the

[1] Letters on Natural Magic, Amer. edit., p. 27, New York, 1832.

visual apparatus, the anatomical sketch of which has been given under the head of *accessory organs;* and afterwards inquire into the various interesting and important phenomena exhibited by this sense. These organs perform but a secondary part in vision. The *orbit* shelters the eye, and protects it from external violence. The *eyebrows* have a similar effect; and, in addition to this, the hair, with which they are furnished, by virtue of its oblique direction towards the temple, and by the sebaceous secretion that covers it, prevents the perspiration from flowing into the eye, and directs it towards the temple or root of the nose. By contracting the eyebrows, they can be thrown forwards and downwards in wrinkles; and can thus protect the eye from too strong a light, especially when coming from above.

The *eyelids* cover the eye during sleep, and preserve it from the contact of extraneous bodies. During the waking state, this protection is afforded by the instantaneous occlusion of the eyelids, on the anticipation of danger to the ball. The incessant nictation likewise spreads the lachrymal secretion over the surface of the conjunctiva, and cleanses it; whilst the movement, at the same time, probably excites the gland to augmented secretion. The chief part of the movement of nictation is performed by the upper eyelid; the difference in the action of the eyelids being estimated, by some physiologists, as four to one. Under ordinary circumstances, according to M. Adelon,[1] it is the levator palpebræ superioris, which, by its contraction or relaxation, opens or closes the eye; the orbicularis palpebrarum not acting. If the levator be contracted, the eyelid is raised and folded between the eye and orbit, and the eye is open; if, on the other hand, the levator be relaxed, or spread passively over the surface of the organ, the eye is closed. In this view, the orbicularis muscle is not contracted, except in extraordinary cases, and under the influence of volition; whilst the closure of the eye during sleep is dependent upon simple relaxation of the levator. The views of M. Broussais[2] on this subject are more satisfactory. He considers, that the open state of the eye, in the waking condition, requires no effort; because the two muscles of the eyelids are so arranged, that the action of the levator is much more powerful than that of the orbicularis; and he adduces, in proof of this, that the eyelids, at the time of death, are half open. On the other hand, the closure of the eye in sleep he conceives to be owing to the contraction of the orbicularis muscle, which acts whilst the others rest. If the opening of the eye were wholly dependent upon the action of the levator palpebræ superioris, its relaxation during insensibility and death ought to be sufficient to close the eye completely; and the orbicularis palpebrarum would be comparatively devoid of function; being only necessary for the closure of the organ under the influence of volition.

It has been found by experiments instituted by Sir Charles Bell,[3] and by M. Magendie,[4] that nictation is effected under the influence chiefly of the portio dura of the seventh pair or facial nerve,—one of the respiratory nerves of Sir Charles Bell's system—the *respiratory of the face.* When this nerve is cut, nictation is completely arrested; and

[1] Physiologie de l'Homme, 2de édit., i. 419, Paris, 1829. [2] Op. citat., p. 188.
[3] The Nervous System of the Human Body, Amer. edit., p. 48, Washington, 1833.
[4] Précis Élémentaire, i. 309.

when the nerve of the fifth pair, also distributed to these parts, is divided, it ceases likewise, but less thoroughly; a very vivid light exciting it, but only at considerable intervals, and imperfectly. We see here something very analogous to the partition of the nerves of the senses into those possessing general, and special sensibility. Like the latter functionaries, the nerve of the seventh pair appears to be *specially* concerned in nictation, and not to be capable of executing its office, unless the fifth pair—the nerve of *general* sensibility—be in a state of integrity. The explanation of Dr. Marshall Hall is different. It has been before remarked, that if the functions of the brain be suspended or destroyed, the true spinal system being uninjured, the orbicularis palpebrarum still contracts so as to close the eyelids, when the tarsus is touched with any solid body. In this case, neither sensation nor volition can be concerned. It is a reflex action; the excitor nerves being probably branches of the fifth, and the motor, branches of the seventh pair. Hence, when the will ceases to act, as in sleep, or in apoplexy, the lids close over the eye to protect it. In the waking state, the levator palpebræ, under the influence of the will, acts as an antagonist to the orbicularis and keeps the eye open; but there is an almost irresistible tendency to close the eye; and, as in the case of respiration, the muscular contraction can only be restrained to a certain degree: it takes place, whenever the condition of the conjunctiva is such as to occasion an impression to be conveyed along the excitor nerve which demands a reflex movement to modify it; for example, when particles of dust collect upon it; or the surface becomes dry.[1]

The eyelids, by their approximation, can regulate the quantity of light that enters the pupil, when it is injuriously powerful; when feeble, they are widely separated, to allow as much light as possible to penetrate the organ. By their agency, again, the most diverging rays from an object can be prevented from falling upon the cornea; and the vision of the myopic or short-sighted can be assisted. It is a means of which they often avail themselves. The *cilia* or *eyelashes*, it is probable, are of similar advantage as regards the admission of light into the eye, and, probably, have some part in preventing extraneous bodies, borne about in the air, from reaching the sensible conjunctiva.

The *muscles* of the eyeball have acquired the chief portion of their interest in recent times, and largely through the investigations of the eminent physiologist—of whose labours we have so frequently had occasion to speak—Sir Charles Bell.[2] The arrangement of the four *straight* muscles, and especially their names, sufficiently indicate the direction in which they are capable of moving the organ, when acting singly. If any two of them contract together, the eyeball will, of course, be moved in the direction of the diagonal between the two forces; and if each muscle contracts rapidly after the other, the organ will execute a movement of circumduction. The *oblique* muscles are in some respects antagonists to each other, and roll the eye in opposite directions; the superior oblique directing the pupil downwards and inwards; the inferior upwards and inwards. But as the different

[1] Carpenter, Human Physiology, p. 154, London, 1842.

[2] Op. citat., p. 102, and Anatomy and Physiology, 5th Amer. edit., ii. 213, New York, 1827.

straight muscles are capable of carrying the eye in these directions, were we to regard the two sets of muscles as possessing analogous functions, the oblique would appear to be superfluous. This, along with other reasons, attracted the attention of Sir Charles Bell to the subject; and the result of his experiments and reflections was;—that the straight muscles are concerned in the motions of the eye excited by volition; and that the oblique muscles are the organs of its involuntary motions. In this manner, he accounts for several phenomena, connected with the play of the organs in health and disease. Whilst the power of volition can be exerted over the recti muscles, the eye is moved about, in the waking state, by their agency; but, as soon as volition fails from any cause, the straight muscles cease to act, and the eye is turned up under the upper eyelid. Hence this happens at the approach of, and during sleep; and whenever insensibility occurs from any cause, as in faintness, or on the approach of dissolution; and the turning up of the eyeball, which we have been accustomed to regard as the expression of agony, is but the indication of a state of incipient or total insensibility. Whenever, too, the eyelids are closed, the eyeball is moved, so that the cornea is raised under the upper eyelid. If one eye be fixed upon an object, and the other be closed with the finger so placed as to feel the convexity of the cornea through the upper eyelid, and the open eye be shut, the cornea of the other eye will be found to be elevated. This change takes place during the most rapid winking motions of the eyelids; and is obviously inservient to the protection of the eye; to the clearing of the eyeball of everything that could obscure vision, and perhaps, as Sir Charles Bell presumes, to procure the discharge from the ducts of the lachrymal gland. During sleep, when the closure of the eye is prolonged, the transparent cornea is, by this action, turned up under the upper eyelid, where it is securely lodged and kept moist by the secretions of the lachrymal gland, follicles, and conjunctiva.

The different distributions of the motor nerves of the eye have been described in the anatomical sketch. It was there stated, that the superior oblique muscle receives one whole pair of nerves,—the fourth. This nerve, then, it seemed to Sir Charles Bell, must be concerned in the functions we have described; and, as the various involuntary motions of the eyeball are intimately concerned in expression, as in bodily pain, and in mental agony,—in which the action of the direct muscles seems, for a time, to be suspended,—he was led to consider the fourth as a nerve of expression,—a respiratory nerve; and, hence, intimately connected with the facial of the seventh pair, which, as has been already remarked, is the great nervous agent in the twinkling of the eyelids. Anatomical examination confirmed this view,—the roots of the nerve being found to arise from the same column as other respiratory nerves. The coincidence of this twinkling, and of the motion of the eyeball upwards, was, therefore, easily understood.

There is a difficulty, however, here, which has doubtless already suggested itself to the reader. The fourth pair is distributed to the superior oblique only; the lesser oblique receives none of its ramifications. They cannot, therefore, be identically situate in this respect. Yet

they are both considered by Sir Charles Bell as involuntary muscles. The action, indeed, of the lesser oblique would appear to be even more important than that of the greater oblique, as the function of the former, when acting singly, is to carry the eye upwards and inwards; and, when the action of its antagonist is abolished, this is more clearly manifested. Sir Charles found, that the effect of dividing the superior oblique was to cause the eye to roll more forcibly upwards;—in other words, it was given up, uncontrolled, to the action of the antagonist muscle. This difficulty, although it is not openly stated by Sir Charles, must have impressed him; for, after having referred to the effect of the division of the superior oblique, he is constrained to suggest an influence to the fourth pair, which would, we think, be anomalous;—that it may, on certain occasions, cause a *relaxation* of the muscle to which it goes, and, in such case, the eyeball must be rolled upwards. In addition to this, too, as Mr. Mayo[1] has observed, the distribution of the muscular nerves of the eye is not such as to allow of our opposing the straight muscles to the oblique; and one cogent reason is, that the third pair supplies part of each class.

We have still, therefore, much to learn regarding this subject, into which so much interest, and, at the same time, so much uncertainty has been infused. In some experiments on the fresh subject, made by the author with Professor Pancoast, who carefully separated the different muscles, with the view of discovering their precise action, it was clearly apparent, that the oblique muscles act in the manner above mentioned; the superior oblique directing the eye slightly inwards and downwards; and the inferior rolling it upwards and inwards, when they acted singly; when the two were brought into action, simultaneously, they appeared to antagonize each other as rotators, but projected the eye forward. It would seem, indeed, that an important use of these muscles is to keep the eye prominent during the action of the straight muscles.

These results harmonize greatly with the deductions from experiments on living animals by Mr. Bransby Cooper.[2] He divided the superior and inferior oblique muscles of the eyes of several living rabbits: and inferred, that the oblique muscles, when acting together, suspend the eyeball in a central position in the orbitar cavity; moderate the retracting influence of the four straight muscles; and, when acting in succession, without being restricted by the influence of the straight muscles, they roll the eye on its own axis, drawing the globe forward, and at the same time tending, in a great degree, to extend the sphere of vision.[3]

The great use of the *tears* would seem to be to moisten the conjunctiva, and to remove extraneous bodies from its surface,—thus assisting the motions of the eyelids and eyeball. The tears are secreted by the lachrymal gland; and, by means of its excretory ducts, are poured upon the surface of the tunica conjunctiva, at the upper and outer part of the eyeball. Their farther course towards the puncta lacrymalia has

[1] Outlines of Human Physiology, 4th edit., p. 299, London, 1837.
[2] Guy's Hospital Reports, vol. iii., April and October, 1838.
[3] See, on all this subject, Carpenter's Principles of Human Physiology, 5th Amer. edit., p. 913, Philad., 1853.

been the subject of difference of sentiment. Many physiologists have considered that, owing to the form of the tarsal cartilages, a canal exists, when the eyelids are closed, of a triangular shape, formed anteriorly by the junction of the cartilages, and behind by the ball of the eye. M. Magendie,[1] on the other hand, denies the existence of this canal; and asserts that the tarsal cartilages do not touch by a rounded edge, but by an inner plane surface. If we were to grant the existence of this canal, it could only aid us in our explanation of the course of the tears during sleep. In the waking state, they are not ordinarily secreted in such quantity as to require that much should pass to the puncta;—the movements of nictation spreading them over the surface of the eye, whence they are partly absorbed, and the rest, perhaps, evaporated. Under extraordinary circumstances, however, the gland increases its secretion so much, that the tears not only pass freely through the lachrymal ducts into the nose, but flow over the lower eyelid. The *epiphora* or *watery eye*, caused by obstruction of these ducts, also proves that a certain quantity of the secretion must always be passing into the puncta. The physical arrangement of the eyelids and tunica conjunctiva is doubtless the cause of their course in this direction.

It has been gratuitously supposed by some, that the humour of Meibomius prevents the tears from reaching the outer surface of the lower eyelid, by acting like a layer of oil on the margin of a vessel filled with water. A similar function has been assigned to the secretion of the caruncula lacrymalis. Both these fluids, however, are probably inservient to other ends. They are readily miscible with water; become consequently dissolved in the tears, and, with the assistance of the fluid secreted by the tunica conjunctiva, aid the movements of the eyelids over the ball of the eye, and keep the tarsal margins and their appendages in the condition requisite for the due performance of their functions.

The action of the puncta themselves in admitting the tears has received different explanations. M. Adelon[2] regards it as organic and vital. We ought, however, in all cases, to have recourse to this mode of accounting for phenomena as the *ultima ratio;* and the present appears to be a case in which it is singularly unnecessary. In many of the results of absorption we are compelled to suppose, that a vital operation must have been concerned in the process. Where, for example, as in the case of the lymphatic vessels, we find the *same* fluid circulating, whatever may have been the nature of the substances whence it was obtained, the evidence, that a vital action of selection and elaboration has been going on, is irresistible; but there is no such action in the case in question. The tears in the lachrymal ducts and ductus ad nasum are identical with those spread upon the surface of the eye. This is one of the few cases in the human body, which admit of satisfactory explanation on the physical principles of capillary attraction. In vegetables, the whole of the circulation of their juices has been thus accounted for. If we twist together several threads of

[1] Précis, &c., edit. cit., i. 52.
[2] Physiologie, 2de édit., p. 421, Paris, 1829.

yarn; moisten them; and put one extremity of the roll into a vessel of water, allowing the other to hang down on the outside and to dip into an empty vessel placed below it,—we find, that the whole of the fluid in the first vessel is in a short time transferred to the second. If, again, we take a small capillary tube, less than the twentieth part of an inch in diameter, and place it so as to touch the surface of water, we find, that the water rises in it to a height, which is greater, the smaller the bore of the tube. If the diameter of the tube be the fiftieth part of an inch, the water will rise to the height of two inches and a half; if the one hundredth part of an inch, to five inches; if the two hundredth part of an inch, to ten inches; and so on. Now, the punctum lacrymale is, in our view of the subject, the open extremity of a capillary tube, which receives the fluid of the lachrymal gland and conveys it to the nose,—the punctum being properly directed towards the eyeball by the tensor tarsi muscle of Horner, and the inspiratory movements drawing it down the ductus ad nasum.

Lastly:—the *tunica conjunctiva* is another part of the guardian apparatus of the eye. It secretes a fluid, which readily mixes with the tears, and appears to have similar uses. Like mucous membranes in general, it absorbs; and, in this way, a part of the lachrymal secretion is removed from its surface. An animal, for the same reason, can be readily poisoned by applying hydrocyanic acid to it. As the conjunctiva lines the eyelids, and is reflected over the globe, it supports the friction, when the eyeball or eyelids are moved; but, being highly polished and always moist, this is insignificant.

The extreme sensibility of the outer part of the eye appertains to the tunica conjunctiva, and is dependent on the ophthalmic branch of the fifth pair. When this nerve was divided in a living animal, M. Magendie[1] found, that the membrane became entirely insensible to every kind of contact, even of substances that destroyed it chemically. In his experiments on this subject, he arrived at singular results, regarding the influence of the fifth nerve on the nutrition of the eye. When the trunk of the nerve was divided within the cranium a little after its passage over the petrous portion of the temporal bone, the cornea was found, about twenty-four hours afterwards, to become troubled; and a large spot to form upon it. In the course of from forty-eight to sixty hours, the part was completely opaque; and the conjunctiva, as well as the iris, in a state of inflammation; a turbid fluid was thrown out into the inner chamber, and false membranes proceeded from the interior surface of the iris. The crystalline and vitreous humours now began to lose their transparency; and, in the course of a few days, were entirely opaque. Eight days after the division of the nerve, the cornea separated from the sclerotica; and the portions of the humours that remained fluid escaped at the opening. The organ diminished in size, and ultimately became a kind of tubercle, filled with a substance of a caseous appearance. M. Magendie properly concludes from these experiments, that the nutrition of the eye is under the influence of the fifth pair; and he conceives, that the opacity of the cornea was directly owing to the section of this nerve, and not to

[1] Précis Élémentaire, ii. 494.

a cessation of the lachrymal secretion, or to the prolonged contact of air, caused by the paralysis of the eyelids; inasmuch as when only the branches of the nerve proceeding to the eyelids were divided, or when the lachrymal gland was taken away, the opacity did not supervene.

5. PHENOMENA OF VISION.

It has been more than once remarked, that the retina—the expansion of the optic nerve—is the part of the eye which receives the impressions of luminous rays, whence they are conveyed by that nerve to the brain. Yet this has been contested.

The Abbé Mariotte[1] discovered the singular fact, that when a ray of light falls, as he conceived, upon the centre of the optic nerve it excites no sensation. "Having often observed," he remarks, "on dissections of men as well as of brutes, that the optic nerve does never answer just to the middle of the bottom of the eye; that is, to the place where the picture of the object we look directly upon is made; and that in man it is somewhat higher, and on the side towards the nose; to make therefore the rays of an object to fall upon the optic nerve of my eye, and to find the consequence thereof, I made this experiment. I fastened on an obscure wall, about the height of my eye, a small round paper, to serve me for a fixed point of vision. I fastened such another on the side thereof towards my right hand, at the distance of about two feet, but somewhat lower than the first, to the end that I might strike the optic nerve of my right eye, while I kept my left shut. Then I placed myself over against the first paper, and drew back by little and little, keeping my right eye fixed and very steady on the same, and being about ten feet distant, the second paper totally disappeared."

Fig. 297.

Experiment of Mariotte.

The experiment of Mariotte can be readily repeated on the marginal representations of the *fleur-de-lis* and arrow. If we close the left eye, and direct the axis of the right eye steadily towards the arrow, when the page is held at the distance of about ten inches from the eye, the *fleur-de-lis* vanishes. The distance of the object which disappears from the eye must be about five times as great as its distance from the other object. In this case the *fleur-de-lis* and arrow are two inches asunder. It is obvious, from what has been said, regarding the axis of the orbits, and the part of the eyeball at which the optic nerve enters—that rays of light from an object can never fall, at the same time, upon the insensible point of each eye. The defect in vision is, consequently, never experienced except in such experiments as those performed by Mariotte. In one of these he succeeded in directing the rays to the insensible point of both eyes at once. He put two round papers at the height of the eye, and at the distance of three feet from each other. By then placing himself opposite them, at the distance of twelve or thirteen feet, and holding his thumb before his eyes, at the distance of

[1] Philos. Transact., iii. 668, and Mémoir. de l'Académie Royale des Sciences, tom. i. pp. 68 and 102.

about eight inches, so that it concealed from the right eye the paper on the left hand, and from the left eye the paper on the right, he looked at his thumb steadily with both eyes, and both the papers were lost sight of. These experiments show, that there is a part of the retina or optic nerve, which is, in each eye, insensible to light; and that this point—*punctum cæcum*—is on the nasal side of the axis. No sooner, however, had Mariotte published an account of his experiments, than it was decided that this spot was the basis of the optic nerve; a conclusion was accordingly drawn, that the nerve is incapable of distinct vision, and this conclusion has been embraced, without examination, in many of the books on optics to the present time. Although probable, however, it is by no means certain that the light, in these cases, falls upon the base of the nerve. The direction in which the ray proceeds is such that it is reasonable to suppose it does impinge there: the suggestion of M. Tillaye,[1] that it falls upon the yellow spot of Sömmering, can only be explained by presuming him to have been in utter ignorance of the situation of the yellow spot, which, we have seen, is on the outer side of the nerve.

But, granting that the light falls at the base of the optic nerve, it by no means demonstrates, that the *nerve* is incapable of receiving the impression. It has been already shown, that the central artery of the retina penetrates the eye through the very middle of the nerve; and that through the same opening, the central vein leaves the organ. It is probable, therefore, that, in these experiments, the ray falls upon the bloodvessels, and not upon the medullary matter of the nerve; and if so, we could not expect that there should be sensation. That the insensible spot is of small magnitude is proved by the fact, that if a candle be substituted for the round paper or wafer, the candle does not disappear, but becomes a cloudy mass of light. Daniel Bernouilli[2] —it is true—considered the part of the nerve insensible to distinct impressions to occupy about the seventh part of the diameter of the eye, or about the eighth of an inch; but there must have been some error in his calculations, for the optic nerve itself can rarely equal this proportion. The estimate of Le Cat,[3] who was himself a believer in the views of Mariotte, that its size is about one-third, or one-fourth of a line, is probably still wider from the truth in the opposite direction. Simple experiment, with two wafers placed upon a door at the height of the eye, shows clearly, that both the horizontal and vertical diameters of the spot must be larger than this.[4]

The fact, observed by Mariotte, was not suffered to remain in repose. A new hypothesis of vision was framed upon it; and, as he considered it demonstrated, that the optic nerve was insensible to light, he drew the inference, that the retina is so likewise; and as vision was effected in every part of the interior of the eye, except at the base of the optic nerve, where the choroid is alone absent, he inferred that the choroid must be the true seat of vision. The controversy, at one time

[1] Adelon, Physiologie, 2de édit., i. 448, Paris, 1829.
[2] Haller, Element. Physiolog., xvi. 4, 4.
[3] Traité des Sens, p. 166, Paris, 1767; or English translation, Lond., 1750.
[4] Medical and Physiological Problems, by William Griffin, M. D., and Daniel Griffin, M. D., p. 113, Lond., 1845.

maintained on this subject, has died away, and it is not our intention to disturb its ashes, farther than to remark, that De La Hire,[1] who engaged in it, entertained the opinion, that the retina receives the impression of the light in a secondary way, and through the choroid coat as an intermediate organ; and that by the light striking the choroid, the membrane is agitated, and the agitation communicated from it to the retina. The views of De La Hire are embraced by Sir David Brewster,[2] as well as by numerous other philosophers.

The opinions of Mariotte have now few supporters. The remarks already made regarding the optic nerve; the effect of disease of the retina, of the nerve itself, and of its roots, compel us to regard its expansion as the seat of vision; and if we were even to admit, with Mariotte, that the insensible portion is really a part of the medullary matter of the nerve, and not a bloodvessel existing there, we could still satisfactorily account for the phenomenon by the anomalous circumstances in which the nervous part of the organ is there placed. The choroid coat, of great importance in the function, as well as the pigmentum nigrum, is absent; and hence we ought not to be surprised, that the function is *imperfectly* executed:—we say *imperfectly*, for the experiment with the candles exhibits, that the part is not really insensible to light, or is so in a very small portion of its surface only. It may seem at first sight, that the fact of this defect existing only in the centre of the optic nerve, or at the *porus opticus* as it has been termed, where the central artery of the retina enters, and the corresponding vein leaves the organ, militates against the idea of its being caused by the rays impinging upon these vessels; as, if so, we ought to have similar defects in every part of the retina, where the ramifications of these vessels exist. Circumstances are not here, however, identical. When the ray falls upon the porus opticus, it strikes the vessels in the direction of their length; but, in the other cases, it falls transversely upon them, pierces them, and impresses the retina beneath; so that, under ordinary circumstances, little or no difference is perceived between the parts of the retina over which the vessels creep, and others. We can, however, by an experiment of Purkinje, described by J. G. Steinbuch,[3] exhibit, that under particular circumstances such difference really does exist, and renders the bloodvessels of the organ perceptible to its own vision. If, without closing the eyelids, the left eye be covered with the hand, or some other body, and a candle or lamp be held in the right hand, within two or three inches of the right eye, but rather below it, (keeping the eye directed straight forward,) on moving the candle slowly from right to left, (or if the candle be held on the right side of the eye, it may be moved up and down,) a spectrum appears, after a short time, in which the bloodvessels of the retina, with their various ramifications, are distinctly seen projected, as it were, on a plane without the eye, and greatly magnified. They seem to proceed from the optic nerve, and to consist of two upper and two lower branches, which ramify towards the field of vision, where a dark

[1] Mém. de l'Académie, tom. ix.

[2] Treatise on Optics, Amer. edit., by A. D. Bache, p. 243, Philad., 1833.

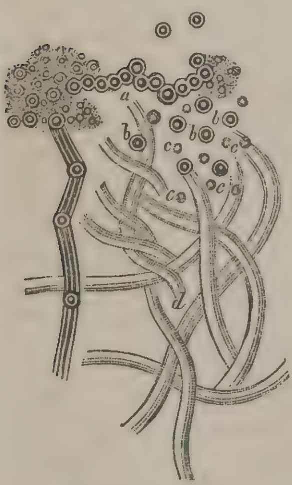
[3] Beitrag zur Physiologie der Sinne, Nürnberg, 1811; and J. Müller, Elements of Physiology, by Baly, ii. 1163, Lond., 1839.

spot is seen, corresponding to the foramen centrale. The origin of the vessels is a dark oval spot, with an areola. This phenomenon must be accounted for by the parts of the retina, covered by the bloodvessels, not being equally fatigued with those that are exposed.

It is by no means uncommon for appearances of cobwebs, small tubes with lateral pores, &c., to present themselves before the eyes, without changing their position when the eyes are fixed upon an object. These appearances are not owing to any modification in the humours, but are apparently dependent upon the physical condition of the retina. Some years ago, a tube of the kind mentioned, but apparently terminating in an open mouth, was the occasion of some uneasiness to the author. This is now no longer seen, but numerous opacities, somewhat resembling plexuses of vessels or nerves, are still apparent. All these appearances are usually called collectively "*muscæ volitantes.*"

They have been described by Mr. T. W. Jones[1] under three forms:—*first*, as a convoluted string of beads, or a convoluted transparent tube, containing in its interior a row of beads smaller than its diameter, except here and there where one larger than the rest is seen occupying its whole diameter,—the end of the string or tube sometimes presenting a dark knobbed extremity, as if formed by an aggregation of the beads composing the string, or contained within the tube (Fig. 298, *a*); *secondly*, insulated beads, some of which—and these are more frequent, have a well-defined outline *b*;—others, and these are rarer, have a distinct outline *c*; and *thirdly*, a parcel of flexuous round watery-looking or spun-glass-like filaments with dark contours, often divided inferiorly into truncated branches, *d*.

Fig. 298.



Muscæ Volitantes.

The muscæ, which change their position, would appear to be seated in the humours of the eye; and it has been supposed in the vitreous more especially: whence the term *ento-hyaloid muscæ* given to them.

It has been remarked, that the rays, proceeding from the upper part of an object, impinge upon the lower portion of the retina; and those from the lower part on the upper; hence the image of the object is reversed, as in Fig. 295. It has, accordingly, been asked;—how it is, that we see the object in its proper position, as its image is inverted on the retina? Buffon,[2] Le Cat,[3] and others believed, that, originally, we do see them so inverted; but that the sense of touch apprises us of the error, and enables us to correct it at so early a period, and so effectually, that we are afterwards not aware of the process. This cannot apply, however, to the lower animals; and, accordingly, the knot has

[1] The Principles and Practice of Ophthalmic Medicine and Surgery, Amer. edit., p. 323, Philad., 1847.

[2] Mémoires de l'Académie, 1743, p. 231.

[3] Op. citat.

been cut by the supposition—and there is much to favour it—that in them it is innate or intuitive.[1] Berkeley,[2] again, asserted, that the position of objects is always judged of, by comparing them with our own; and that, as we see ourselves inverted,—and this view is embraced by Müller, Volkmann,[3] and numerous others,—external bodies are in the same relation to us as if they were erect. It is not necessary to reply at length to these views. Cases enough have occurred of the blind from birth having been restored to sight to show, that no such inversion, as that described by Buffon, takes place; and the boy, who stoops down, and looks at objects between his legs, although he may be, at first, a little confused, from the usual position of the images on the retina being reversed, soon sees as well in that way as in any other. The great error with all these speculatists has been, that they have imagined a true picture to be formed on the retina, which is regarded by the mind, and therefore *seen* inverted. It need hardly be said, that there is no interior eye to take cognizance of this image; but that the mind accurately refers the impression, made upon the retina, to the object producing it; and if the lower part of the retina be impressed by a ray from the upper part of an object, this impression is conveyed by the retina to the brain as it receives it, and no error can be indulged. Professor Alison[4] offers an explanation, first suggested to him by Mr. Dick, veterinary surgeon, which turns on the alleged fact, that the course of the optic nerves and tractus optici is such, that impressions on the upper part of the retina are, in fact, impressions on the lower part of the optic lobes,—that impressions on the outer part of the former are on the inner part of the latter,—and conversely.

Mr. Bain[5] is of opinion, that to make the seeing of objects erect by means of an inverted image on the retina a phenomenon demanding explanation is to misapprehend entirely the process of visual perception. "An object seems to us to be up or down according as we raise or lower the pupil of the eye in order to see it. The very notion of up and down is derived from our feelings of movement, and not at all from the optical image formed on the back of the eye. Wherever this image was formed, and however it lay, we should consider that to be the top of the object, which we had to raise our eyes or our body to reach."

When a cone of light proceeds from a radiant point, as from B, Fig. 295, the whole of the rays,—whatever may be their relative obliquity,—are, as has been seen, converged to a focus upon the retina at *b*, yet the point B is seen only in one direction, in that of the central ray or axis of the cone B *b*. If we look over the top of a card at the point B, till the edge of the card is just about to hide it; or if, in other words, we obstruct all the rays that pass through the pupil, excepting the uppermost, the point is still seen in the same direction as when it was viewed

[1] Carpenter, Human Physiology, p. 266, Lond., 1842.

[2] Essay on Vision, 2d edit., p. 60, Dublin, 1709.

[3] Wagner's Handwörterbuch der Physiologie, 14te Lieferung, S. 342, Braunschweig, 1846.

[4] On Single and Correct Vision, by means of Double and Inverted Images on the Retinæ, in Transact. of the Royal Society of Edinburgh, vol. xiii., Edinb., 1836.

[5] The Senses and the Intellect, by Alexander Bain, A. M., p. 233, Lond., 1855.

by the whole cone proceeding from B. If we look, again, beneath the card, in a similar manner, so as to see the object by the lowest ray of the cone, the radiant point will be equally seen in the same direction. Hence, says Sir David Brewster,[1] it is manifest, that the line of visible direction does not depend on the direction of the ray, but is always perpendicular to the retina; and as the surface of the retina is a portion of a sphere, those perpendiculars must all pass through one point, "which may be called the *centre of visible direction;* because every point of a visible object will be seen in the direction of a line drawn from this centre to the visible point."

The point *o*, Fig. 295, is, in Sir David's view, the centre of visible direction. Where a luminous cone proceeds in the direction of the axis of the eye, the centre of visible direction will fall in that line, and a perpendicular, drawn from the point *b*, where the rays of the cone meet at a focus on the retina, will pass through this centre of visible direction *o*, and the same thing, he conceives, will apply to every other pencil of rays. Thus, the rays from D and E, which fall upon the cornea at *t*, will be refracted so as to impinge upon the retina at *s* and *r* respectively; and D and E will be seen in the direction of lines drawn from these points to the centre of visible direction, *o*.

This "law of visible direction" removes at once, Sir David Brewster thinks, every difficulty that besets the subject of the cause of erect vision from an inverted image on the retina. The lines of visible direction necessarily cross each other at the centre of visible direction, so that those from the lower part of the image go to the upper part of the object; and those from the upper part of the image to the lower part of the object.

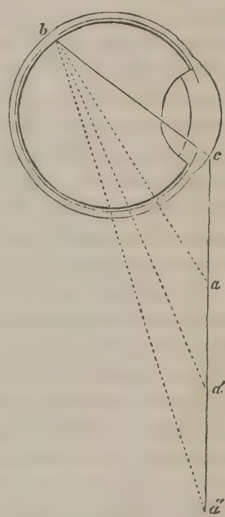
The views of Sir David are embraced by Mr. Mayo,[2] who considers them confirmed by the fact—to which reference has already been made—that any pressure made upon the retina through the eyeball causes a spectrum to be seen in a direction *opposite* to the point compressed; as well as by the following experiments of Scheiner, by whom this law of visual direction was first shown. If the head of a pin, strongly illuminated, be viewed with one eye at a distance of four inches, that is, within the common limit of distinct vision, the object is seen large and imperfectly defined,—the outermost cones of rays, which enter the pupil from each point, being too divergent to be collected to a focus on the retina. If a card pierced with a pinhole be now interposed between the eye and the object, the latter may be seen distinctly defined through the pinhole by means of rays that have entered the pupil nearly parallel, with a slightly divergent tendency. But the object may be seen by rays passing either through the upper or lower part, the right or left side, or the centre of the pupil. On shifting the card for this purpose, the object appears to move in an *opposite direction.*—Or, if three pinholes be made, one in the centre, and one at either side, the object appears tripled; and if one of the side holes be closed, the *opposite* of the three objects disappears: if, for example, the left-hand pinhole be closed, the right object disappears.—Again, if the head of a pin, strongly illuminated, be viewed at the distance of eighteen inches,

[1] Op. citat., p. 246. [2] Outlines of Human Physiology, 3d edit., p. 277.

its outline is distinct and clear; the rays passing from each point of the object are brought to a point on the retina, but they reach the retina at different angles; and, by interposing a card perforated with a single pinhole, the object may be seen by rays, which enter the upper part, or the lower part, or the centre of the pupil. No change, however, in the visual place of the object occurs in this instance, as the card is being shifted; nor is the image multiplied when seen through several pinholes in the card.

The last experiment, says Mr. Mayo, proves, that the angle at which rays of light fall upon the retina does not affect our notion of the place of objects; and, taken with the preceding, establishes as an inductive law, that *the retina is so constituted, that, however exerted, each point of it sees in one direction only*, that direction being a line vertical to it; or that in every instance of vision, *each point of an object is seen in the direction of a line vertical to the point of the retina upon which the rays proceeding from it are collected.* It would seem, however, to be a forcible objection to this view of the subject; that all the objects, a, a' and a'' on the line ca'', Fig. 299, must fall upon exactly the same point of the cornea: and, therefore, upon the same point of the retina; yet, as only one of these lines $b\ a$ is perpendicular to the point of the retina on which the rays are collected, such a perpendicular would obviously refer the position of the object a alone correctly. Moreover, accurate examination would appear to show, that this law of visible direction cannot be optically correct, as the lines of direction cross each other at a point much anterior to the centre of the eyeball. This may be proved by making a diagram of the eye on a large scale, and laying down the course of the rays entering the organ, according to the curvatures, and refractive powers of its different parts. In this manner, Volkmann[1] found, that the lines of direction cross each other at a point a little behind the crystalline, and that they will thus fall at such different angles on different points of the retina, that no general law can be deduced respecting them.

Fig. 299.



Lines of Visible Direction.

A certain intensity of light is necessary, in order that the retina may be duly impressed, and this varies in different animals; some of which, as we have seen, are capable of exercising the function of vision in the night, and have hence been termed *nocturnal.* In man, the degree of light necessary for distinct vision varies according to the previous state of the organ. A person, passing from a brilliantly illuminated room into the dark, is, for a time, incapable of seeing any thing; but this effect differs in individuals; some being much more able to see distinctly in obscurity than others. This is owing to the

[1] Neue Beiträge zur Physiologie des Gesichtsinnes, Leipzig, 1836, and Müller's Elements of Physiology by Baly, p. 1170, Lond., 1839. See, on this subject, Medical and Physiological Problems, &c., by N. Griffin, M. D., and Daniel Griffin, M. D., p. 97, Lond., 1845.

retina being more sensible; and, consequently, requiring a less degree of light to impress it. On the other hand, a very powerful light injures the retina, and deprives it, for a time, of its function; hence the unpleasant impression produced by the introduction of lights into a room, where the company have been previously sitting in comparative obscurity; or, by looking at the sun. The effect upon the retina, thus induced, is called *dazzling*. If the light that falls upon the eye is extremely feeble, and we look long and intensely upon any minute object, the retina is fatigued; the sensibility of its central portion becomes exhausted, or it is painfully agitated; and the objects appear and disappear, according as it has recovered or lost its sensibility; a kind of remission seeming to take place in the reception of the impressions.

These affections are considered by Sir David Brewster[1] as the source of many optical deceptions, which have been ascribed to a supernatural origin. "In a dark night, where objects are feebly illuminated, their disappearance and reappearance must seem very extraordinary to a person whose fear or curiosity calls forth all his powers of observation. This defect of the eye must have been often noticed by the sportsman, in attempting to mark, upon the monotonous heaths, the particular spots where moor-game had alighted. Availing himself of the slightest difference of tint in the adjacent heaths, he endeavours to keep his eye steadily upon it as he advances; but, whenever the contrast of illumination is feeble, he almost always loses sight of his mark, or if the retina does take it up a second time, it is only to lose it again."

In all the cases, in which the eye has been so long directed to a minute object that the retina has become fatigued, on turning the axis slightly away from the object, the light from it will fall upon a neighbouring part of the retina, and the object be again perceived, and in the mean time the part, previously in action, will have recovered from its fatigue. By the fact of the retina becoming fatigued by regarding an object for a long time we explain many interesting phenomena of vision. If the eye be directed, for a time, to a white wafer laid upon a black ground; and afterwards to a sheet of white paper, it will seem to have a black spot upon it, of the same size as the wafer;—the retina having become fatigued by looking at the white wafer. On the other hand, if the eye be turned to a black wafer, placed upon a sheet of white paper; and afterwards to another part of the sheet, a portion of the paper, of the size of the wafer, will seem strongly illuminated;—the ordinary degree of light appearing intense, when compared with the previous deficiency. It is on this, that the whole theory of *accidental colours*, as they are called, rests. When the eye has been for some time regarding a particular colour, the retina becomes insensible to this colour; and if, afterwards, it be turned to a sheet of white paper, the paper will not seem to be white, but will be of the colour that arises from the union of all the rays of the solar spectrum, except the one to which the retina has become insensible. Thus, if it be directed for some time to a *red* wafer, the sheet of paper will seem to be of a *bluish-green*, in a circular spot of the same dimensions as the wafer. This bluish-green image is called an *ocular spectrum*, because

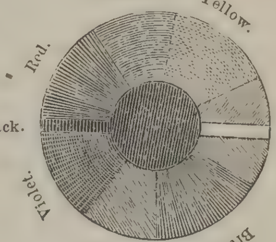
[1] Op. citat., p. 250.

it is impressed upon the eye, and may be retained for a short time; and the colour *bluish-green* is said to be the *accidental colour* of the *red.* If this experiment be made with wafers of different colours, other accidental colours will be observed, varying with the colour of the wafer employed, as in the following table:—

Colour of the Wafer.	Accidental Colour, or Colour of the Ocular Spectrum.
Red,	Bluish-green.
Orange,	Blue.
Yellow,	Indigo.
Green,	Violet, with a little red.
Blue,	Orange-red.
Indigo,	Orange-yellow.
Violet,	Yellow-green.
Black,	White.
White,	Black.

If all the colours of the spectrum be ranged in a circle, in the proportions they hold in the spectrum itself, as in Fig. 300,—the accidental colour of any particular colour will be found directly opposite. Hence the two have been termed *opposite colours.*

Fig. 300.



Accidental Colours.

It will follow, from what has been said, that if the primary colour, or that to which the eye has been first directed, be added to the accidental colour, the result must be the same impression as that produced by the union of all the rays of the spectrum—of *white* light. The accidental colour, in other words, is what the primitive colour requires to make it colourless light. The primitive and accidental colours are, therefore, *complements* of each other; and hence accidental colours have been called *complementary colours.* They have likewise been termed *harmonic,* because the primitive and its accidental colour *harmonize* with each other in painting. It has been supposed, that the formation of these ocular spectra has frequently given rise to a belief in supernatural appearances,—the retina, in certain diseased states of the nervous system, being more than usually disposed to retain the impressions, so that the spectrum remains visible for a long time after the cause has been removed. Such appears to be the view of Drs. Ferriar,[1] Hibbert,[2] and Alderson,[3]—the chief writers in modern times, on apparitions. This subject may be the theme of future discussion. It will be sufficient, at present, to remark, that the great seat and origin of spectral illusions is the brain, and that the retina is no farther concerned than it is in dreaming or in the hallucinations of insanity.

[1] An Essay towards a Theory of Apparitions, Lond., 1813.
[2] Sketches of the Philosophy of Apparitions, Edinb., 1825.
[3] An Essay on Apparitions, &c., Lond., 1823.

The retina is able to receive visual impressions over its whole surface, but not with equal distinctness or accuracy. When we regard an extensive prospect, that part of it alone is seen sharply, which falls upon the central part, or in the direction of the axis of the eye: we always, therefore, in our examination of minute objects, endeavour to cause the rays from them to impress this part of the retina;—the distinctness of the impression diminishing directly as the distance from the central foramen increases. This central point, called the *point of distinct vision*, is readily discriminated on looking at a printed page. It will be found, that although the whole page is represented on the retina, the letter to which the axis of the eye is directed is alone sharply and distinctly seen; and, accordingly, the axis of the eye is directed in succession to each letter as we read. In making some experiments on indistinctness of vision at a distance from the axis of the eye, Sir David Brewster[1] observed a singular peculiarity of oblique vision, namely,—that when we shut one eye and direct the other to any fixed point, such as the head of a pin, and hence see all other objects within the sphere of vision indistinctly, if one of these objects be a strip of white paper, or a pin lying upon a green cloth, after a short time, the strip of paper or the pin will altogether disappear, as if it were entirely removed, the impression of the green cloth upon the surrounding parts of the eye extending itself over the part of the retina, which the image of the pin occupied. In a short time, the vanished image will re-appear, and again vanish. When the object seen obliquely is luminous, as a candle, it never vanishes entirely, unless its light is much weakened by being placed at a great distance; but it swells and contracts, and is encircled with a nebulous halo,—the luminous impressions extending themselves to adjacent parts of the retina not directly influenced by the light itself.

From these, and other experiments of a similar character, Sir David infers, that oblique or indirect vision is inferior to direct vision, not only in distinctness, but from its inability to preserve a sustained vision of objects. Yet it is a singular fact, that *indirect* has a superiority over *direct* vision in the case of minute objects, such as small stars, which cannot, indeed, be seen by the latter. A mode frequently adopted by astronomers for obtaining a view of a star of the last degree of faintness is to direct the eye to another part of the field, and in this way, a faint star, in the neighbourhood of a large one, often becomes very conspicuous, so as to bear a certain illumination, and yet it entirely disappears, as if suddenly blotted out, when the eye is turned full upon it; and, in this way, it can be made to appear and disappear as often as the observer pleases. Sir J. F. W. Herschel, and Sir James South, who describe this method of observation, attempt to account for the phenomenon by supposing, that the lateral portions of the retina, being less fatigued by strong light, and less exhausted by perpetual attention, are probably more sensible to faint impressions than the central ones; and the suggestion carries with it an air of verisimilitude. Sir David Brewster, however,—from the result developed by his experiments, that, "in the case of indirect vision, a luminous

[1] Op. citat., p. 248.

object does not vanish, but is seen indistinctly, and produces an enlarged image on the retina, besides that which is produced by the defect of convergency in the pencils,"—concludes somewhat mystically, "that a star, seen indirectly, will affect a large portion of the retina from these two causes, and, losing its sharpness, will be more distinct."[1]

In order that the image of any object may impress the retina, and be perceived by the mind; it must, first of all, occupy a space on the retina sufficiently large for its various parts to be appreciated: in the next place, the image must be distinct or sharp,—in other words, the luminous rays that form it must converge accurately to a focus on the retina; and lastly, the image must be sufficiently illuminated. Each of these conditions varies with the size of the body, and the distance at which it is from the eye; and there are cases, where they are all wanting, and the object is consequently invisible. An object may be so small, that the eye cannot distinguish it, because the image, formed on the retina, is too minute. To remedy this inconvenience, the object must be brought near to the eye, which increases the divergence of the rays and the size of the image; but if we approach it too close to the eye, the rays are not all brought to a focus on the retina, and the image is indistinct. If, therefore, an object be so small, that, at the visual point, to be presently mentioned, the rays proceeding from it do not form an image of sufficient size on the retina, the object is not seen. To obviate this imperfection of the sense, minute bodies may be viewed through a small hole in a piece of paper or card, or with the instrument called a *microscope.* By looking through the small aperture in the paper or card, the object may be brought much nearer to the eye; the rays of greatest divergence are prevented by the smallness of the hole from impinging upon the retina; and the rest are converged to a focus upon that membrane, so that a sharp and distinct impression is received. The iris is, in this way, useful in effecting distinct vision,—the most divergent rays being, by the contraction of the pupil, prevented from falling upon the crystalline.

Any object that does not subtend an angle of the sixtieth of a degree is invisible; but the visual power differs greatly in individuals. Some eyes are much more capable of minute inspection than others; and greater facility is acquired by practice. Professor Ehrenberg, however, found, that in regard to the extreme limits of vision, there is little difference among persons of ordinarily good sight, whatever may be the focal distance of their eyes. The smallest square magnitude usually visible to the naked eye, either of white particles on a black ground, or of black upon a white ground, is about the $\frac{1}{405}$th of an inch; but particles that reflect light powerfully, as gold dust, may be discovered with the naked eye in common daylight, when not exceeding the $\frac{1}{1125}$th of an inch; and, when the substance viewed is in lines instead of particles, it may be seen, if held towards the light, when only $\frac{1}{4900}$th of an inch in diameter.

Again, there is a point of approximation to the eye beyond which objects cease to be distinctly seen, in consequence of the rays of light striking so divergently upon the eye, that the focus falls behind the

[1] Op. citat., p. 249.

retina. This point, too, varies according to the refractive power of the eye; and is, therefore, different in different individuals. In the myopic or short-sighted, it is much nearer the eye than common; in the presbyopic or long-sighted, more distant. The iris here, again, plays an important part, by its action in shutting off the most diverging rays.

There is also a limit beyond which objects are no longer visible. This is owing to the light from them becoming absorbed before it reaches the retina, or so feeble as not to make the necessary impression. The distance, consequently, at which an object may be seen, will depend upon the sensibility of the retina, and partly on the colour of the object; a light colour being visible to a greater distance than a darker. A distant object may also be imperceptible owing to the image, traced on the retina, being too minute to be appreciated; for the size of the image diminishes as the distance of the object increases. The range of distinct vision varies, likewise, with the individual,—and especially with the myopic and presbyopic; and in such case the pupil dilates to admit as much light as possible into the interior of the eye, and to compensate in some measure for the defect.

Between the ranges of distant and near vision, a thousand different examples occur. In all cases, however, the ocular cone must be brought to a focus on the retina, otherwise there cannot be perfect vision. It has been already observed, in the proem on light, that the distance, at which the ocular cone arrives at a focus behind the lens, is in proportion to the length of the objective cone; or, in other words, that the focus of a lens varies with the distance at which a radiant point is situate before it: where the point is near the lens the focus will be more remote behind it; and the contrary. If this occurs in the human eye it must necessarily follow;—either that it is not necessary for an object to be impressed upon the retina;—or that the eye is capable of accommodating itself to distances;—or if it does not occur, it must be admitted, that, owing to the particular constitution of the eye, the impressions are so made on the retina as not to need such adaptation. The whole bent of the foregoing observations on vision would preclude the admission of the *first* of these postulates. The *second* has been of almost universal reception, and given rise to many ingenious speculations; and the *third* has been seriously urged of late years only.

It would occupy too much space to dwell at length upon the various ingenious discussions, and the many interesting and curious experiments, that have resulted from a belief in the power possessed by the eye of accommodating itself to distances. It is a subject, however, which occupies so large a field in the history of physiological opinions, that it cannot be passed over. The chief views, that have been entertained, are:—*First.* The cornea or lens must recede from, or approach the retina, according to the focal distance, precisely as we adapt our telescopes by lengthening or shortening the tube. *Secondly.* If we suppose the retina to be stationary, the lens must experience a change in its refractive powers, by an alteration of its shape or density; or, *Thirdly.* In viewing near objects, those rays only must be admitted, which are nearest the axis of the eye, and are consequently least diverging.

1. The hypothesis, that the adjustment of the eye is dependent upon an alteration of the antero-posterior diameter of the organ, or on the relative position of the humours and retina, has been strongly supported by many able physiologists. Blumenbach[1] was of opinion, and his views seem to have been embraced by Dr. Hosack,[2] that the four straight muscles of the eye, by compressing the eyeball, cause a protrusion of the cornea, and thus increase the length of the axis. Dr. Monro secundus[3] believed, that the iris, recti muscles, the two oblique, and the orbicularis palpebrarum participate in the accommodation; and Hamberger, Briggs,[4] and others, that the oblique muscles, being thrown in opposite directions around it, may have the effect of elongating the axis of the eye. Kepler[5] thought, that the ciliary processes draw the crystalline forward, and increase its distance from the retina. Des Cartes[6] imagined the same contraction and elongation to be effected by muscularity of the crystalline, of which he supposed the ciliary processes to be the tendons;—Porterfield,[7] that the corpus ciliare is contractile, and capable of producing the same effect;—Jacobson,[8] that the aqueous humour, by entering the canal of Petit through the apertures in it, distends the canal, and pushes the crystalline forward;—Sir Everard Home,[9] that the muscular fibres, which he has described as existing between the ciliary processes, move the lens nearer to the retina, and that the lens is brought forward by other means, (which he leaves to conjecture,) when the distance of the object is such as to require it;—Dr. Knox,[10] that the annulus albus, or the part which unites the choroid and sclerotic coats, is muscular, and the chief agent in this adjustment;—Professor Mile,[11] of Warsaw, that the contraction of the iris changes the curvature of the cornea; whilst Sir David Brewster[12] thinks it "almost certain, that the lens is removed from the retina by the contraction of the pupil."

Without examining these and other views in detail, it may be remarked, that the nicest and most ingenious examination by the late Dr. Young[13] could not detect any change in the length of the axis of the eyeball. To determine this, he fixed his eye, and at the same time forced in upon the ball the ring of a key, so as to cause a very accurately defined phantom within the field of perfect vision; then looking to bodies at different distances, he expected, if the figure of the eye were modified, that the spot, caused by the pressure, would be altered in shape and dimensions; but no such effect occurred; the power of accommodation was as extensive as ever, and there was no perceptible

[1] Instit. Physiolog., § 276, or Elliotson's translation.
[2] Philosoph. Transact. for 1794, p. 146.
[3] Three Treatises on the Brain, the Eye, the Ear, p. 137, Edinb., 1797.
[4] Nova Visionis Theoria, Lond., 1685. [5] Haller, Element. Physiol., xvi. 4, 2.
[6] De Homine, p. 45, Lugd. Bat., 1664.
[7] A Treatise on the Eye, the Manner and Phenomena of Vision, Edinb., 1759.
[8] Magendie, Précis, &c., i. 78.
[9] Philosoph. Transact. for 1794, 1795, 1796, and 1797; and Lectures on Comparative Anatomy, iii. 213, Lond., 1823.
[10] Edinb. Philos. Transact., x. 56.
[11] Magendie, Journal de Physiologie, vi. 166; and Elliotson's Human Physiology, p. 571, Lond., 1840.
[12] Edinburgh Journal of Science, i. 77; and Treatise on Optics, edit. citat., p. 253.
[13] Philos. Transact. for 1795.

change either in the size or figure of the oval spot. Again, Sir Everard Home asserts, that all the ingenuity of the distinguished mechanician, Ramsden, was unable to decide, whether, in the adjustment of the eye, there be any alteration produced in the curvature of the cornea. These facts would alone induce a doubt of the existence of this kind of adjustment, even if we had not the additional evidence, that many animals are incapable of altering the shape of the eyeball, by the muscles at least. The cetacea, the ray amongst fishes, and the lizard amongst reptiles, have the sclerotica so inflexible as to render any variation in it impossible.

With regard to many of the particular views that have been mentioned, they are mere "cobwebs of the brain," and unworthy of serious argument. In the action of the orbicularis palpebrarum, as suggested by Dr. Monro, there is, however, something so plausible, that many persons have been misled by it. He made a set of experiments to show, that this muscle, by compressing the eyeball, causes the cornea to protrude, and thus enables the eye to see near objects more distinctly. When he opened his eyelids wide, and endeavoured to read letters, which were so near the eye as to be indistinct, he failed; but when he kept the head in the same relation to the book, brought the edges of the eyelids within a quarter of an inch of each other, and made an exertion to read, he found he could see the letters distinctly. But Sir Charles Bell[1] properly remarks on this experiment, that if the eyelids have any effect upon the eyeball by their approximation, it must be to flatten the cornea; and that the improvement in near vision produced by such approximation is owing to the most divergent rays being shut off,—as in the experiment of the pinhole through paper.

Dr. Carpenter[2] thinks that, so far as we can at present judge, a change in the place of the lens is the sole means of adapting the eye for distant objects; and he is disposed to believe, with Dr. Clay Wallace, Messrs. Todd and Bowman, and others, that this is effected by the action of the ciliary muscle (Fig. 287), and also, he thinks, by the erectile tissue of the ciliary processes; for although—he remarks —no such change can be demonstrated by observation, yet it can be shown, that the contraction of the ciliary muscle would tend to draw the lens forward; and the fact, that this muscle is peculiarly powerful in the predaceous birds, which are distinguished for their great range of vision, and which have, in their circle of osseous sclerotic plates, an unusually firm point of attachment for it, he considers a strong argument in favour of this view.

2. The second hypothesis, which attributes the adaptation to a change of figure in the crystalline itself, has been embraced by all who regard that body to be muscular, and therefore by Leeuwenhoek,[3] Des Cartes,[4] and Dr. Young.[5] These muscular fibres, however, could never be excited by Dr. Young to contraction so as to change the

[1] Anat. and Physiology, Amer. edit. by Dr. Godman, ii. 227, New York, 1827.

[2] Principles of Human Physiology, Amer. edit., p. 669, Philad., 1855.

[3] Boerhaav. Prælect., § 527, tom. iv. p. 92; and Haller, Element. Physiol., lib. xvi. sect. 2.

[4] Op. cit.

[5] Op. cit.

focal power; and their very existence is more than doubtful. The increasing density of the lens towards its centre indicates rather a cellular structure, the cells being filled with transparent matter of various degrees of concentration; and an examination into its intimate physical constitution affords no evidence of muscularity.

Professor Forbes,[1] of Edinburgh, embraced the view, that the adaptation is owing to a change of figure in the crystalline; but his explanation of its mode of production varies from that given by preceding writers. The lens, he says, is composed of coats more firm and tenacious, as well as more refractive towards the centre, and less so at the sides. These coats are also nearly spherical in the centre, forming a nucleus of considerable resistance. Hence he supposes, that if the lens be compressed in any manner by a uniform hydrostatic pressure, it will yield more readily in a plane at right angles to the axis of vision; and the lens will become more spheroidal, and consequently more refractive,—that is, adapted for the vision of objects at small distances. This hydrostatic pressure is believed to be conveyed from the humours of the eye, between which the lens is delicately suspended, and to originate in the action of the muscles that move the eyeball compressing simultaneously the tough sclerotic coat.

It is somewhat singular, that on a subject where so many opportunities have occurred for establishing the fact definitively, such difference of opinion should exist regarding the question, whether an eye from which the crystalline has been removed, as in the operation for cataract, be capable of adjusting itself to near objects. Haller[2] and Knox, amongst others, decide the question affirmatively; Porterfield, Young, and Travers,[3] negatively. M. Magendie, as we have seen, considers the great use of the crystalline to be,—to increase the brightness and sharpness of the image by diminishing its size. Mr. Travers again, regards the adjustment as a change of figure in the lens; not, however, from a contractile power in the part itself, but in consequence of the lamellæ, of which it is composed, sliding over each other, when acted upon by external pressure; whilst upon the removal of this pressure, its elastic nature restores it to its former sphericity. The iris is conceived to be the agent in this process,—the pupillary part of the organ being, in the opinion of Mr. Travers, a proper sphincter muscle, which, when it contracts and relaxes, tends, by the intervention of the ciliary processes, to effect a change in the figure of the lens, which produces a corresponding change in its refractive powers.

3. One of the causes to which the faculty of seeing at different distances has been ascribed is the contraction and dilatation of the pupil. It has been already observed, that when we look at near objects, the pupil contracts, so that the most divergent rays do not penetrate the pupil; and vision is distinct. Hence, it has been conceived probable, by De La Hire,[4] Haller,[5] and others, that the adjustment of the eye to

[1] Proceedings of the Royal Society of Edinb., No. 25, cited in the Amer. Journ. of the Med. Sciences, Oct., 1845, p. 504.

[2] Element. Physiol., lib. xvi. sect. 4.

[3] A Synopsis of the Diseases of the Eye, Lond., 1824.

[4] Mémoir. de l'Acad. des Sciences de Paris, tom. ix. p. 620.

[5] Element. Physiol., tom. v. lib. xvi., 4.

various distances within the limits of distinct vision may be effected by this mechanism, in the same manner as it regulates the quantity of light admitted into the organ. Certain it is, that if we look at a row of minute objects, extending from the visual point outwards, the pupil is seen to dilate gradually as the axis of the eye recedes from the nearest object.

An experiment made by the author, on his own eye,[1] when a student of medicine, has been quoted by Dr. Fleming[2] as confirmatory of this view. The extract of belladonna has the power, when applied to the eyelids, of dilating the pupil. A newly prepared article was thus applied, and in the space of about twenty minutes the pupil was so much dilated, that the iris was almost invisible. From the time that preternatural dilatation occurred, objects, presented to this eye with the other closed, were seen as through a cloud. The focus was found to be at twice the distance of that of the sound organ; but, in proportion as the effects of the belladonna passed off, and the pupil approached its natural size, vision became more and more distinct, and the focus nearer and nearer the natural. In the open air, all objects except those near were distinctly seen; but, on entering a room, all was enveloped in mist.

The catoptric experiments of Cramer are more satisfactory, perhaps, in demonstrating a change in the curvature of the lens than any that have been recorded. In viewing distant objects, the eye appeared to him to be at rest; but on viewing near objects, a special action was apparent, which, he considered, consisted in the lens being carried more forwards. That such was the fact was, indeed, shown by the following experiment. It has been already remarked,[3] that when a candle is held before the eye, three distinct images are seen; the nearest and the most distant being upright, and formed respectively by reflection from the cornea and the anterior surface of the crystalline; and the one in the middle inverted, and formed by reflection from the posterior concave surface of the crystalline. When the eye is accommodated for distant vision, or is at rest, the hindmost and middle images are very near each other; but when the curvature of the lens changes, the position of the images changes; when the eye was directed to near objects, Cramer noticed that the hindmost and middle images became larger than when distant objects were regarded. This phenomenon he referred to a considerable increase in the curvature of the lens, and he accounts for it by the pressure exerted on the lens by the contraction of the iris. The power of accommodation he found to be lost by destruction of the iris.[4]

There is, indeed, more evidence in favour of the utility of contraction and dilatation of the pupil in distinct vision, within certain limits at least, than of any of the other supposed methods of adjustment; and, accordingly, the majority of opticians of the present day embrace this view of the subject; but without being able to explain satisfactorily the change in the interior of the eye effected by its movements. "It seems difficult," says Sir David Brewster[5]—one of the latest writers—

[1] Annals of Philosophy, x. 432.
[2] Philosophy of Zoology, i. 187, Edinb., 1822.
[3] Page 79.
[4] Budge, Memoranda der Speciellen Physiologie des Menschen, S. 346, Weimar, 1853.
[5] Op. citat., p. 252.

"to avoid the conclusion, that the power of adjustment depends on the mechanism, which contracts and dilates the pupil; and as this adjustment is independent of the variation of its aperture, it must be effected by the parts in immediate contact with the base of the iris. By considering the various ways, in which the mechanism at the base of the iris may produce the adjustment, it appears to be almost certain, that the lens is removed from the retina by the contraction of the pupil." The conclusion, drawn by Sir David, does not, however, impress us with the same degree of certainty.

Müller[1] thinks it most probable, that the faculty of the eye, which enables it to adjust itself to different distances, depends on an organ, which has a tendency to act by consent with the iris, but yet is in a certain degree independent of it. Reasoning *per exclusionem*, he thinks it most probable, that the ciliary body has this motor power, and this influence on the position of the lens; but admits, that we have no positive proof of its possessing contractility. More recently, however, as has been shown,[2] the existence of a ciliary muscle has been demonstrated, which, by its contraction, may directly or indirectly advance the lens. M. Pouillet, in his lectures before the *Faculté des Sciences* of Paris,[3] explains the matter with no little confidence by the double effect of the crystalline being composed of different layers, and the mobility of the pupil;—a view, which had been previously maintained in its essential characters by Treviranus.[4] As these layers are thinner towards the axis of the crystalline than near its edges, by detaching them successively the curvature of the remainder becomes greater and greater, until the most central portion has the shape of a sphere. Hence, such an apparatus will not have one focus only, but several,—as many, in fact, as there are superposed layers;—the foci being nearer and nearer as we approach the central spherical portion. This arrangement, he says, enables us to see at all distances, inasmuch as, "having an infinite number of foci at our disposal, we can use the focus that suits the object we are desirous of viewing." If, for example, it be a near object, the pupil contracts, so as to allow the rays to fall only on the central parts; if more distant, the pupil is dilated to permit the rays to pass through a part that has a more distant focus.

It is obvious, however, that in such a case, the ordinary inconvenience of the aberration of sphericity must result; for when the pupil is dilated, the rays must pass through the more marginal, as well as the central part of the lens. M. Pouillet was aware of this difficulty, but he has not disposed of it philosophically. "It may be said that in opening the pupil widely, the light is not precluded from passing by the centre, and that a kind of curtain would be required to cover the part of the lens, which is unemployed. To this I reply, that there is no necessity to prevent the rays from passing by the axis of the crystalline; for what is the light, which passes through this small space,

[1] Elements of Physiology, by Baly, P. v. p. 1150, June, 1839.
[2] Baly and Kirkes, Recent Advances in the Physiology of Motion, the Senses, &c., p. 24, Lond., 1848.
[3] Élémens de Physique Expérimentale, t. iii. p. 331, Paris, 1832.
[4] Beiträge zur Anatom. und Physiol. der Sinnenwerkzeuge u. s. w., 1828.

compared with that which passes through the great zone of the crystalline? It may be looked upon as null."

It must be admitted, with Mr. Longet,[1] that if the fact of the adaptation of the eye to vision at different distances be received as incontestable, the mechanism of the phenomenon must be regarded as entirely unknown; not one of the explanations offered being able to carry conviction. The whole affair is, indeed, enveloped in perplexity, and it is rendered not less so by the fact mentioned by M. Magendie, that if we take the eye of an albino animal, and direct it towards a luminous object, we find a perfect image depicted on the retina, whatever may be the distance of the object;—the image, of course, being smaller and less luminous when remote, but always distinct. Yet, in this experiment, the eye being dead, there can be neither contraction nor dilatation of the pupil. This result has induced Magendie,[2]—and not too hastily, perhaps,—to draw the conclusion, that although theory may suggest, that there ought to be such adaptation as has been presumed and attempted to be accounted for, observation proves, that such may not be the case; and, consequently, all the speculations on the subject, however ingenious they may be, must fall to the ground. Dr. Fletcher, too, after alluding to the various hypotheses on the subject, adds:—"It appears absurd to attempt to explain a fact which has no real existence, since it has never been proved that the eyeball has any capability of adapting itself to different distances, or that any such adaptation is required."[3] We are, indeed, not justified, perhaps, in admitting more than a slight accommodation from the contraction of the pupil in viewing near objects, effected in the mode already explained. If the accommodation existed to any material extent, it is difficult to understand, why minor degrees of short or long-sightedness should not be rectified. Sir Charles Bell[4] conceives, "that the mechanism of the eye has not so great a power of adapting the eye to various distances as is generally imagined, and that much of the effect, attributed to mechanical powers, is the consequence of the motion of the pupil and the effect of light and of attention. An object looked upon, if not attended to, conveys no sensation to the mind. If one eye is weaker than the other, the object of the stronger eye alone is attended to, and the other is entirely neglected; if we look through a glass with one eye, the vision with the other is not attended to." "The mind," he adds, "not the eye, harmonizes with the state of sensation, brightening the objects to which we attend. In looking on a picture or panorama, we look to the figures, and neglect the background; or we look to the general landscape, and do not perceive the near objects. It cannot be an adaptation of the eye, but an accommodation, and association of the mind with the state of the impression."

The view, which we have expressed upon the subject, is confirmed by the calculations of different investigators. From the refractive powers of the different media of the eye it was calculated by Olbers, that the difference between the focal distances of the images of an

[1] Traité de Physiologie, ii. 70, Paris, 1850.
[2] Précis Élémentaire, i. 72.
[3] Rudiments of Physiology, Part iii. p. 48, Edinburgh, 1837.
[4] Anat. and Physiology, edit. cit., ii. 230.

object at such distance that the rays are parallel, and of one at the distance of four inches, is only about 0.143 of an inch; so that the change in the distance of the retina from the lens required for vision at all distances, supposing the cornea and lens to maintain the same form, would not be more than about a line. Again:—M. de Simonoff,[1] a learned Russian astronomer, asserts, that from a distance of four inches to infinity the changes in the angle of refraction are so small that the apices of luminous cones, in a properly formed eye, must always fall within the substance of the retina; and hence no variation in the shape of the eye, according to the distance of the object, can be necessary. Such facts amply justify the interrogatory of M. Biot;[2]—whether the aberration of the focus for different distances may not be compensated in the eye by the intimate composition of the refractive bodies, as the aberration of sphericity probably is? Yet, if this be the case, how admirable must be the construction of such an instrument! How far surpassing any effort of human ingenuity! An instrument capable of not only correcting its own aberrations of sphericity, and refrangibility, but of seeing at all distances.[3]

It has been before observed, that the *visual point* varies in different individuals. As an average, it may be assumed at eight inches from the eye. There are many, however, who, either from original conformation of the organ, or from the progress of age, wander largely from this average; the two extremes constituting *myopy* or *short-sightedness*, and *presbyopy* or *long-sightedness.*

In the *myopic* or *short-sighted* the visual point is so close, that objects cannot be seen unless brought near the eye. This defect is owing to too great a refractive power in the transparent parts of the organ; or to too great a depth of the humours; or it may be caused by unusual convexity of the cornea or crystalline; or from the retina being too

Fig. 301.

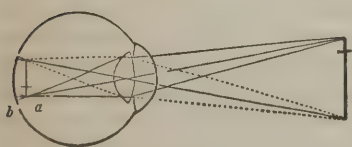
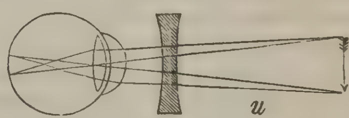


Fig. 302.



Myopic Vision.

distant from the latter. From any one or more of these causes, the rays of light proceeding from distant objects are brought to a focus before they reach the retina, and the objects consequently are not distinctly visible. (Fig. 301.) To see them distinctly, they must be placed close to the eye, in order that the rays may fall more divergently; and the focus be thrown farther back so as to impinge upon the retina. The

[1] Magendie's Journal de Physiologie, tom. iv. and Précis de Physiol., i. 73.

[2] Traité de Physiologie Expérimentale, Paris, 1816.

[3] Letters of Euler, by Sir D. Brewster, Amer. edit., i. 163, New York, 1833. See, on this subject, Volkmann, Art. Sehen, in Wagner's Handwörterbuch der Physiologie, 14te Lieferung, S. 295, Braunschweig, 1846; and Baly and Kirkes, Recent Advances in the Physiology of Motion, the Senses, Generation and Development, p. 20, Lond., 1848.

defect may be palliated by the use of concave glasses, which render the rays, proceeding from the object, more divergent. It is by no means unfrequent in youth; and the myope has been consoled with the common belief, that, in the progress of life, and in the alterations which take place in the eye from age, he is likely to see well without spectacles, when others of the same age may find them essential. It is probable, however, that this is, in many cases at least, a vulgar error; as we have known different myopic sexagenarians, who have not experienced the slightest improvement.

The *presbyope*, *presbytic*, or *long-sighted*, labours under an opposite defect. The visual point is much more distant than the average; and

Fig. 303.

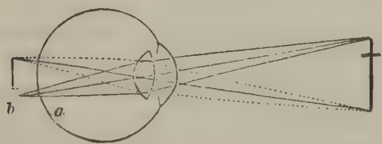
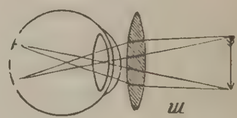


Fig. 304.



Presbyopic Vision.

he is unable to see an object unless it is at some distance. This condition is owing to too feeble a refractive power in the transparent parts of the eye; to insufficient depth of the eyeball; to too close an approximation between the retina and crystalline; or to too little convexity of the cornea or crystalline; so that the rays of light proceeding from a near object are not rendered sufficiently convergent to impinge upon the retina; but fall behind it. This defect, which is experienced more or less by most people after middle age, is palliated by the use of convex glasses, which render the rays proceeding from an object more convergent, and enable the eye to refract them to a focus farther forward, or on the retina.

Although the presbyopic eye is unusual in youth, it is sometimes met with. A young friend, at ten or twelve years of age, was compelled to employ spectacles adapted to advanced life; and this was the case with several of the members of a family, to whom the arts have been largely indebted in this country. One of them, at twenty, was compelled to wear spectacles which were almost microscopes.

Both the myopic and the presbyopic conditions exist in a thousand degrees; and hence it is impossible to say, *à priori*, what is the precise lens, that will suit any particular individual. This must be decided by trial. The opticians have their spectacles arbitrarily numbered to suit different periods of life; but each person should select for himself such as will enable him to read without effort at the usual distance. A degree of myopy may be brought on by long-protracted attention to minute and near objects, as we observe occasionally in the watchmaker and engraver; and, again, a person who has been long in the habit of looking out for distant objects, as the sailor, or the watchman at signal stations, is rendered less fitted for minute and near inspection. During the domination of Napoleon, when the conscript laws were so oppressive, the young men frequently induced a myopic state, by the constant

use of glasses of considerable concavity;—the defect being esteemed a sufficient ground of exemption from military service.

The power of bi-convex glasses is indicated by their numbers, and these numbers indicate the inches of the focal length. The numbering of the French glasses, whether presbyopic or myopic, has a much more extensive range than the British, as is shown by the following lists.

Presbyopic (French) 80, 72, 60, 48, 36, 30, 24, 20, 18, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, $4\frac{1}{2}$, 4, $3\frac{1}{2}$, 3, $2\frac{1}{2}$, 2, $1\frac{3}{4}$, $1\frac{1}{2}$, 1.

Myopic (French) 60, 30, 20, 18, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, $4\frac{1}{2}$, 4, $3\frac{3}{4}$, $3\frac{1}{2}$, 3, $2\frac{3}{4}$, $2\frac{1}{2}$, 2, $1\frac{3}{4}$, $1\frac{1}{2}$, $1\frac{1}{5}$, 1.

Presbyopic (British) 48, 36, 30, 24, 20, 18, 14, 12, 10, 9, 8, 7, 6, $5\frac{1}{2}$, 5, $4\frac{1}{2}$, 4, $3\frac{5}{8}$, $2\frac{3}{4}$, $2\frac{5}{8}$ $2\frac{1}{2}$, $2\frac{2}{10}$, 2, $1\frac{3}{4}$, $1\frac{1}{2}$.

Myopic (British) 00, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20.[1]

The numbers of the double convex glasses below 5, in both scales, are confined to patients who have undergone the operation for cataract.

In England, the lowest power in use for presbyopia is a glass of 48 inch focus. In France, as the table shows, one of much lower power is used. It would not appear, however, that any sensible difference can be perceived between these powers in most cases, so far as assistance to the sight is concerned.[2] In this country, a power lower than 48 inches is rarely used; but occasionally one of 60 or 80 inches is employed.

Another subject, which has given rise to much disputation and experiment, is, why, as we have two eyes, and the image of an object is impressed upon each of them, we do not see such object double? Smith[3] and Buffon[4] consider, that in infancy we do see it so; and that it is not until we have learned by experience,—by the sense of touch, for example,—that one object only exists, that we acquire the power of single vision. After the mind has thus become instructed of its error, a habit of rectification is attained, until it is ultimately effected unconsciously. The objections to this hypothesis are many and cogent. We are not aware of any instance on record, in which double vision has been observed in those, who, having laboured under cataract from birth, have received their sight by an operation; and we are obviously precluded from knowing the state of vision in the infant, although the simultaneous and parallel motions of the eyes, which are manifestly instinctive, and not dependent upon habit, would induce us to presume, that the images of objects—as soon as the parts have attained the necessary degree of developement—are made to fall upon corresponding points of the retina. It may, also, be remarked, in favour of the instinctive nature of this parallel motion of the eyes, that in the blind,—although we may find much irregularity in the motions of the eyeball, owing to no necessity existing for the eyes being directed to any particular point,—the eyeballs move together, unless some deranging influence is exerted. The truth is, as we have already observed, the encephalon is compelled to receive the impression as it is conveyed to

[1] W. White Cooper, art. Vision, in Cyclop. of Anatomy and Physiology, iv. 1467, London, 1852.

[2] Ibid.

[3] Optics, Cambridge, 1738.

[4] Mémoir. de l'Academ. des Sciences, 1743.

it; and even in cases, in which we are aware of an illusion, the perception of the illusion still exists in spite of all experience. If the finger be pressed on one side of the eyeball, an object, seen in front, will appear double, and the perception of two objects will be made by the brain, although we know from experience that one only exists. This occurs in all the various optical illusions to be presently mentioned.

The effect of intoxication has been adduced in favour of this hypothesis. It is said that in these cases the usual train of mental association is broken in upon, and hence double vision results. The proper explanation, however, of this diplopia of the drunkard rests upon other grounds. The effects of inebriating substances on the brain are to interfere with all its functions; and most sensibly with the voluntary motions, which become irregularly executed. The voluntary muscles of the eye partake of this vacillation, and do not move in harmony, so that the impressions are not made on corresponding points of the retina, and double vision necessarily results.

Another hypothesis has been, that although a separate impression is made upon each retina,—in consequence of the union of the optic nerves the impressions are amalgamated, and arrive at the encephalon, so as to cause but one perception. This was the opinion of Briggs,[1] and Ackermann; and at one time it was generally received. Dr. Wollaston[2] supposed the consentaneous motion of the eyes to be connected with the partial union of the optic nerves. The anatomical and physiological facts relating to the union and decussation of these nerves have already engaged us. By a reference to that subject it will be found, that a true decussation takes place between them, yet that each eye probably has its distinct nerve from origin to termination; and that no such semi-decussation, as that contended for by Dr. Wollaston, exists. These facts are unfavourable to the hypothesis of amalgamation of impressions: besides, if we press slightly on the eye, we have a double impression, although the relation of the optic nerves to each other is the same; and, moreover, the same explanation ought to apply to audition, in which we have two distinct impressions, but only a single perception;—yet no one conceives that the auditory nerves decussate. The fusion of the two images into one seems to be a mental operation.

Another opinion has been maintained;—that we do not actually receive the perception of two impressions at the same time; and that vision consists in a rapid alternation in the use of the eyes, according as the attention is directed to one or other of them by accidental circumstances. Such was the opinion of M. Dutours.[3] A modification of this view was entertained by Le Cat,[4] who asserts, that, although the right eye is not always the most powerful, it is most frequently employed; and Gall denies, that we use both eyes at the same time, except in the passive exercise of the function. In active vision, he asserts, we always employ one eye only,—sometimes one and sometimes the other; and thus, as we receive but one impression, we necessarily see but one object. In support of this view, he remarks that in many animals the eyes are situate at the sides of the head, so as not to be capable of being directed together to the same object. In them,

[1] Nova Visionis Theoria, Lond., 1685. [2] Philos. Transact. for 1824, p. 222.
[3] Mémoir. présentées à l'Academie des Sciences, &c., t. iii. & iv. [4] Op. citat.

consequently, one eye alone can be used; and he considers this a presumption, that such is the case in man. He remarks farther, that in many cases we use one eye by preference, in order that we may see better—as in shooting or in taking the direction of objects in a straight line; and that although, in other cases, both eyes may be open, we still use but one. In proof of this, he says, if we place a small object between the eyes and a lighted body, and look at the latter, the shade does not fall between the eyes, on the root of the nose, as it ought to do if the body were looked at with both eyes; but on each eye alternately, according as the one or the other is directed to it; and, he adds, if, when we squint voluntarily, we see two objects, it is because one eye sees passively, whilst the other is in activity.[1]

Amongst numerous objections to this view of the subject, a few may be instanced. Every one must have observed how much more vividly an object is seen with both eyes than with one only. The difference according to Jurin[2] is a constant quantity; and, in sound eyes of the ordinary degree of power, amounts to one-thirteenth of the whole effect. But we have experiment to show, that a distinct impression is made upon each eye. If a solar beam be admitted into a dark chamber, and be made to pass through two glasses of tolerable thickness, but of different colours, placed close alongside each other, provided the sight be good and the eyes of equal power, the light perceived will not be of the colour of either of the glasses, but of an intermediate shade; and if this should not happen, it will be found, that the eyes are of unequal power. When such is the case, the light will be of the colour of the glass placed before the stronger eye. These results were obtained in the *Cabinet de Physique* of the *Faculté de Médecine* of Paris, by M. Magendie,[3] in the presence of M. Tillaye the younger.

The existence of this double impression is proved in another way. If we place any tall, slender object a few feet before us, and examine its relative situation compared with a spot on a wall in the distance, we find, that if the spot be hidden by the stick, when both eyes are open, it will become visible to each eye, when used singly; and be seen on the side of the stick corresponding to the eye employed. But Professor Wheatstone[4] has instituted experiments, which place this matter entirely at rest. He has shown, that in viewing an object having length, breadth, and thickness, the perspective projections upon the two retinæ differ according to the distance at which the object is placed before the eyes. If so distant, that to view it the optic axes must be parallel, the two projections are precisely similar; but if so near, that to view it the optic axes must converge, a different perspective projection is presented to each eye, and these perspectives become more dissimilar as the convergence of the optic axes becomes greater. Notwithstanding this dissimilarity between the two pictures, which is in some cases very great, the object is still seen single, although not exactly resembling either of the two pictures on the retinæ.

[1] Adelon, Physiologie, 2de édit., i. 457, Paris, 1829.

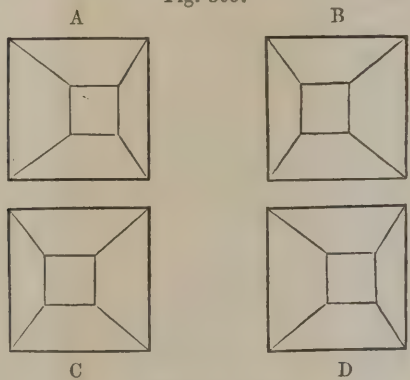
[2] Essay appended to Smith's Optics, Cambridge, 1738; and Haller, Element. Physiol., lib. xvi. 4.

[3] Précis, &c., i. 86. Dutours, in Mém. présentées à l'Académ., iii. 514, & iv. 499.

[4] Philosophical Transactions, P. ii., Lond., 1838.

Having thus established, that the mind perceives an object of three dimensions by means of the two dissimilar pictures projected by it on the two retinæ, Mr. Wheatstone inquired what would be the visual effect of presenting simultaneously to each eye instead of the object itself its projection on a plane surface as it appears to that eye? For this purpose he imagined an instrument which he calls *stereoscope*. It consists of two plane mirrors, with their backs inclined to each other at an angle of 90°, near the faces of which two monocular pictures are so disposed, that their reflected images are seen by the two eyes, each looking into one of the mirrors on the same plane. The experiment may, however, be made sufficiently well by the subjoined figures.

Fig. 305.



Binocular vision.

Fix the right eye on the right-hand figure, and the left eye on the left-hand figure; hold between the eyes, in front of the nose, the board of a duodecimo book. The figures A and B and C and D will be seen to approximate, and to run into each other; A and B representing the skeleton of a truncated four-sided figure in bold relief, whilst C and D represent a depressed or receding pyramid—a fact, which shows, that the visual appreciation of solidity, of projection, or depression arises from the combination in the mind of two different images. All that is necessary, in such cases, is, that the perspective drawings of the object should be an exact representation of the images as they would be impressed upon each eye by the object itself.

All these facts demonstrate, that two impressions are really made in all cases,—one on each eye;—and yet the brain has perception of but one. If the law of visible direction, which Sir David Brewster has pointed out (see page 102), be adopted, the cause of single vision with two eyes must be admitted as a necessary consequence. If we are placed at one end of a room, and direct the axes of both eyes to a circular aperture in a window-shutter at the other end, although an image of this aperture may be formed in each eye, because the lines of visible direction from similar points of the one image meet the lines of visible direction from similar points of the other each pair of similar points will appear as one point, and the aperture seen by one eye will exactly coincide with the aperture seen by the other. But if, when an object is seen single with both eyes, we press one eye aside, the image formed by that eye will separate from the other image, and the object will appear double; or, if the axes of both eyes be directed to a point either nearer or more remote than the aperture in the window shutter, then, in both these cases, the aperture will appear double, because the similar lines of visible direction no longer meet at

the aperture.[1] In Fig. 306, if we look at the object A, the more distant object, B, will be seen double; and in Fig. 307, if we look at the

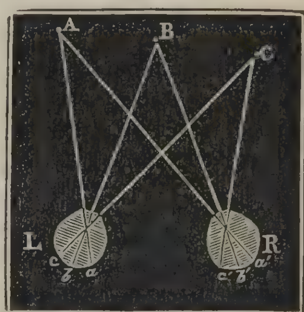
Fig. 306.

Fig. 307.

Binocular Vision.

object B, the nearer object A will be seen double. It is not necessary, however, that the axes of the eyes should be directed accurately on an object, in order that it shall be seen single with both eyes. A whole range of objects may be seen single if their images are thrown on corresponding parts of the retina in both eyes, as in Fig. 308.

Fig. 308.



Binocular Vision.

After all, perhaps the true condition of single vision is, that the two images of an object should be formed on portions of the two retinæ that are accustomed to act in concert. In cases of convergent strabismus, the patient does not see double; but immediately after a successful operation, if the vision of the two eyes be good, he does so; and this continues until the parts of the two retinæ have become habituated to act in concert.

In the course of the preceding remarks, it was stated, that the eyes are not always of the same power. The difference is sometimes surprising. M. Adelon[2] mentions the case of a person, one of whose eyes required a *convex* glass, with a focus of five inches; the other a *concave* glass, with a focus of four inches. In these cases, it is important to use one unassisted eye only; as confusion must necessarily arise from

[1] Optics, p. 44, in Library of Useful Knowledge, Natural Philosophy, vol. i., Lond., 1829, and Treatise on Optics, edit. cit.

[2] Physiologie, edit. cit., i. 459.

directing both to an object. This is the cause why we close one eye in looking through a telescope. The instrument has the effect of rendering the focal distance of the two eyes unequal, and of placing them in the same situation as if they were, originally, of different powers.

From what has been said it will be understood, that if from any cause, as from a tumour pressing upon one eyeball, from morbid debility of the muscles, or from want of correspondence in the sensibility of the two retinæ, the eyes be not properly directed to an object, double vision will be the consequence. In almost all cases, however, of distortion of the eyeballs, the image falls upon a part of one retina, which is more sensible than the portion of the other on which it falls; the consequence will be, that the mind will acquire the habit of attending to the impression on one eye only; and the other may be so neglected, that it will assume a position to interfere as little as possible with the vision of its fellow:—so that, although at first, in *squinting*, there may be a double impression, vision is ultimately single. Buffon,[1] who was of this opinion, affirms, that he examined the eyes of many squinters, and found that they were of unequal power; the weaker, in all cases, having turned away from its direction, and generally towards the nose, in order that fewer rays might reach it, and consequently vision be less interfered with. Yet it is always found, if the sound eye be closed, that the other resumes its proper direction; a fact which disproves the idea of De La Hire[2] and others that the cause of *strabismus* or *squinting* is a difference of sensibility in the corresponding points of the retinæ, and that the discordance in the movements of the organs occurs in order that the images may still fall upon points of the retinæ that are equally sensible. According to this view, both eyes must of course act.

The fact of the diverted eye resuming its proper direction when the sound one is closed is of practical application. Many of the cases of squinting that occur in infancy have been caused by irregular action in the muscles of the eyeball; so that certain of them, from accident or imitation, having been used more frequently than others, the due equilibrium has not been maintained; double vision has resulted; and the affected eye has gradually attained its full obliquity. In these cases, we can, at times, remedy the defect, by placing a bright or conspicuous object in such a position as to exercise the enfeebled muscles; or, we can compel the whole labour of vision to be effected by one eye, and *that* the affected one, which, under the stimulus, will be correctly executed, and, by perseverance, the inequality may be obviated. These, indeed, are the only cases in which we can expect to afford relief; for if the defect be in the interior of the eye, in a radical want of correspondence between the retinæ, or in inequality of the foci, it is irremediable.

It would appear, then, that in confirmed squinting, one eye is mainly, if not solely used, and vision is single,—and that the inclination of one eye inwards may be so great as to deprive it of function, or so slight as to allow the organ to receive rays from the same object

[1] Mém. de l'Académie, 1743, p. 231.

[2] Ibid., tom. ix. 530; Jurin, in Essay appended to Smith's Optics, § 178–194.

as its fellow, and although on different parts of the retina, yet they may become associated; but, in either case, it would seem, that they, who squint habitually, neglect the impressions on the distorted eye, and see with but one.

It has been remarked, that the eyeball of the imperfect eye is drawn towards the nose, in order that as few rays as possible may penetrate the organ, and the vision of the sound eye be less liable to confusion. Sir Everard Home[1] conceives, that it takes this direction in consequence of the adductor muscle being stronger, shorter, and its course more in a straight line than that of any of the other muscles; and Sir Charles Bell[2] ingeniously applies his classification of the muscles of the eye to an explanation of the fact. He asserts, that the recti muscles are in activity whilst attention is paid to the impression on the retina,—but that, when the attention is withdrawn, the recti are relieved, and the eyeball is given up to the influence of the oblique muscles, whose state of equilibrium exists when the eyeball is turned, and the pupil presented upwards and inwards.

Lastly, in persons who are in the habit of making repeated celestial observations, or in those who make much use of the microscope, the attention is so entirely directed to one eye, that the other is neglected, and, in time, wanders about, so as to produce squinting at the pleasure of the individual. In these cases, the eyes become of unequal power; so that one only can be employed where distinct vision is required.

Thus far our remarks have been directed to double vision, where both eyes are employed. We have now to mention a singular fact connected with double and multiple vision with one eye only. The author has distinct double vision with each eye—*uniocular diplopia;*—a lighted lamp, for example, presenting to one, with the other closed, two defined images, the one in advance of the other. If a hair, a needle, or any small object be held before one eye—the other being closed—and within the point of distinct vision, so that the bright light of a lamp or from a window shall fall upon the object in its passage to the eye, or be reflected from it—we appear to see not one object but many. This fact, when it was first observed by the author, appeared to him to have escaped the observation of opticians and physiologists, inasmuch as it had not been noticed in any of the works recently published on optics or physiology. On reference, however, to the excellent "System," of Smith,[3] on the former subject, he found in the "Essay upon Distinct and Indistinct Vision" by Dr. Jurin, appended to it, the whole phenomenon explained, and elucidated at considerable length. The elaborate character of the explanation is probably the cause, why the fact has not been noticed by subsequent writers. The best way of trying the experiment is that suggested by Dr. Jurin. Take a parallel ruler, and opening it slightly, hold it directly before the eye, so as to look at a window or lamp through the aperture. If the ruler be held at the visual point, the aperture will appear to form one luminous line; but if it be brought nearer to

[1] Philos. Transact., 1797, and Lectures on Comparative Anatomy, iii. 238, Lond., 1823.

[2] Anat. and Physiol., edit. cit., ii. 235.

[3] Optics, edit. cit.

the eye, it will appear double; or as two luminous lines, with a dark line between them; and according as the aperture is varied—or the distance from the eye—two, three, four, five or more luminous and dark parallel lines will be perceptible.

At first sight, it might seem, that this phenomenon should be referred to the diffraction or inflection, which light experiences in passing by the edges of a small body,—as the hair or needle. Newton had long ago shown, that, when a beam of light shines upon a hair, the hair will cast several distinct shadows upon a screen, and, of course, present several images to the eye. Dr. Rittenhouse[1] explains, on the same principle, a curious optical appearance, noticed by Mr. Hopkinson, in which, by the inflection of light, caused by the threads of a silk handkerchief, a multiple image of a distant lamp was presented. The objections, however, to the explanation by inflection are,—that the image always appears single, if the object be not *within* the distance of distinct vision;—and that the same multiple image is presented, when the object is seen by reflection, as when we look at a fine line drawn upon paper; or at a fine needle held in a bright light. In this case, a considerable number of parallel images of the needle may be seen, all equally or nearly equally distinct; and not coloured.

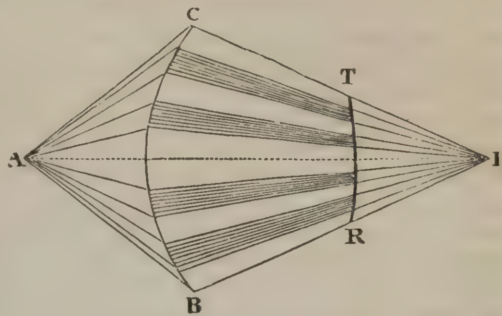
Dr. Jurin considers the phenomena to be caused by fits of easy refraction and reflection of light. Newton demonstrated, that the rays of light are not, in all parts of their progress, in the same disposition to be transmitted from one transparent medium into another; and that sometimes a ray, which is transmitted through the surface of the second medium, would be reflected back from that surface, if the ray had a little farther to go before it impinged upon it. This change of disposition in the rays,—to be either transmitted by refraction, or to be reflected by the surface of a transparent medium,—he called their *fits of easy refraction*, and *fits of easy reflection;* and he showed, that these fits succeed each other alternately at very small intervals in the progress of the rays. Newton does not attempt to explain the origin of these fits, or the cause that produces them; but it has been suggested, that a tolerable idea of them may be formed by supposing, that each particle of light, after its emanation from a body, revolves round an axis perpendicular to the direction of its motion, and presents alternately to the line of its motion an attractive and a repulsive pole, in virtue of which it will be refracted, if the attractive pole be nearest any refracting surface on which it falls; and reflected, if the repulsive pole be nearest the surface.

A less scientific notion of the hypothesis has been suggested,—by supposing a body with a sharp and a blunt end passing through space, and successively presenting its sharp and blunt ends to the line of its motion. When the sharp end encounters any soft body it penetrates it; but when the blunt end encounters the same body, it is reflected or driven back. In applying this explanation to the phenomenon in question, Dr. Jurin presumes, that the light, in passing through the humours of the eye, experiences these fits of easy refraction and easy

[1] Amer. Philos. Transact., vol. ii.

reflection. This will be elucidated by the marginal figure, Fig. 309. Suppose a number of rays of light to proceed from the point A, and to impinge, with different degrees of obliquity, on the denser medium, B C; all the rays that are in fits of easy refraction will pass through the medium to the point D; whilst those that are in fits of easy reflection, will be thrown back into the medium A B C; so that we may presume, that all the rays,

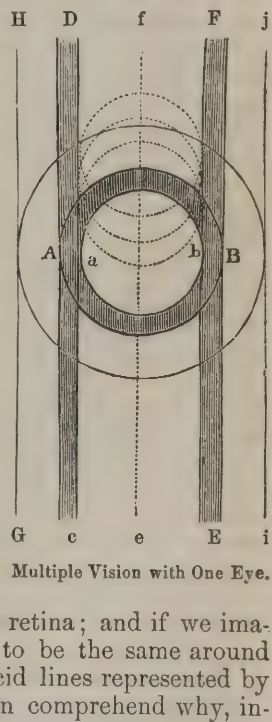
Fig. 309.



Multiple Vision with One Eye.

which fall upon the parts of the medium B C, corresponding to the bases of the dark cones, will be reflected back, whilst those that correspond to the bases of the light cones will pass to a focus at D. Now, if all the bundles of rays, transmitted through the surface B C, be accurately collected into a focus, no other consequence will arise from the other bundles of rays having been reflected back, than that the focus will be less luminous than it would have been had all the rays been transmitted through it. This explains why, at the distance of distinct vision, we have only a single impression made on the eye. But if we approach the object A, so that the focus is not thrown,—say upon the screen R T, which may be presumed to represent the retina—but behind it; the dark and light spaces will be represented upon the screen, and, of course, in concentric circles. This happens to the eye, when the hair or needle or other object is brought nearer to it than the visual point. We can thus understand, why concentric circles, of the nature mentioned, should be formed upon the retina; but how is it, that the objects seen preserve their linear form? Suppose a b, Fig. 310, to be a luminous cone, which in a fit of easy refraction has impinged upon the retina; and A B, b a, the concentric circles, corresponding to the rays that have been reflected. It is obvious, that every point of the object will be

Fig. 310.



Multiple Vision with One Eye.

the centre of so many concentric circles on the retina; and if we imagine the fits of easy reflection and refraction to be the same around those points, we shall have the dark and lucid lines represented by the tangents to these circles; and hence we can comprehend why, instead of having one lucid line e f, we have three, separated by dark

lines parallel to them; and if the light from the luminous point be strong enough to form more lucid rings than are represented in Fig. 310, and the breadth of those rings be not too minute to be perceived, we may have the appearance of five, seven, or more lucid lines, separated by parallel dark lines.

The undulatory theory of light offers another explanation of the phenomenon of fits. The waves in the luminous ether along a ray of light may meet the surface of a transparent body in different conditions of condensation or rarefaction, and their transmission or reflection may be determined by these conditions.

We proceed now to consider the advantages, which the mind derives from the possession of this sense, so pre-eminently entitled to the epithet *intellectual*. Its immediate function is to give us the sensation of light and colour. In this it cannot be supplied by any of the other senses. The action is, therefore, the result of organization; or is a "law of the constitution;" requires no education; but is exercised as soon as the organ has acquired the proper developement. Yet, occasionally, we meet with cases, in which the eye appears to be totally insensible to certain colours, although capable of performing the most delicate functions of vision.

Sir David Brewster[1] has collected several of these cases from various sources. A shoemaker of the name of Harris, at Allonby, in Cumberland, could only distinguish *black* and *white*; and whilst a child, could not discriminate the cherries on a tree from the leaves, except by their shape and size. Two of his brothers were almost equally defective. One of them constantly mistook *orange* for *grass green*, and *light green* for *yellow*. A Mr. Scott, who describes his own case,[2] mistook *pink* for *pale blue*, and full *red* for full *green*. His father, his maternal uncle, one of his sisters, and her two sons, had the same defect. A Mr. R. Tucker, son of Dr. Tucker, of Ashburton, mistakes *orange* for *green*, like one of the Harrises; and cannot distinguish *blue* from *pink*, but almost always knows *yellow*. He mistakes *red* for *brown*, *orange* for *green*, and *indigo* and *violet* for *purple*. A tailor at Plymouth, whose case is described by Mr. Harvey,[3] of Plymouth, regarded the solar spectrum as consisting only of *yellow* and *light blue*; and he could distinguish, with certainty, only *yellow*, *white* and *gray*. He regarded *indigo* and *Prussian blue* as *black*; and *purple* as a modification of *blue*. *Green* puzzled him exceedingly; the darker kinds appearing to him *brown*, and the lighter kinds a pale *orange*. On one occasion, he repaired an article of dress with *crimson* instead of *black* silk; and on another occasion patched the elbow of a *blue* coat with a piece of *crimson* cloth. A still more striking case is given by Dr. Nicholls[4] of a person in the British navy, who purchased a blue uniform coat and waistcoat, with red breeches to match. Sir David Brewster refers to a case that fell under his own observation, where the gentleman saw only the *yellow* and *blue* colours of the spectrum. This defect was ex-

[1] Optics, edit. cit.; Letters on Natural Magic; and art. Optics, in Library of Useful Knowledge.

[2] Philos. Trans. for 1778.

[3] Edinb. Phil. Transact., x. 253.

[4] Medico-Chirurgical Trans., vii. 477, ix. 359.

perienced by Mr. Dugald Stewart,[1] who was unable to perceive any difference between the colour of the scarlet fruit of the Siberian crab and that of its leaves. Dr. Dalton,[2] the chemist and philosopher,—after whom the defect has been most unjustifiably termed *daltonism*,—could not distinguish *blue* from *pink* by daylight; and in the solar spectrum, the *red* was scarcely visible; the rest of it appearing to consist of two colours, *yellow* and *blue*. Mr. Troughton, the optician, was fully capable of appreciating only *blue* and *yellow;* and when he named colours, the terms *blue* and *yellow* corresponded to the more or less refrangible rays:—all those that belong to the former, exciting the sensation of blueness; and those that belong to the latter that of yellowness. Dr. Hays,[3] who has collected the history of numerous cases of achromatopsia,—as this defect has been termed,—and has added the history of one which fell under his own care, was led to infer, from all his researches: 1, that entire inability of distinguishing colours may co-exist with perfect ability to perceive the forms of objects; 2, that the defect may extend to all but one colour, and in such case the colour recognised is always yellow; and, 3, that the defect may extend to all but two colours, and in such case the colours recognised are always yellow and blue;—yet that this is not the fact is sufficiently shown by the examples already given. Dr. Pliny Earle[4] has referred to a number of cases, which came within his knowledge, and most of them under his own observation, in which the inability would seem to have been hereditary. Dr. Earle's maternal grandfather and two of his brothers were characterized by it; and among the descendants of the first mentioned, it is met with in *seventeen*. When thus entailed, it would appear to overleap, at times, one generation or more. It would appear, too, that males are more frequently affected than females. M. Cunier,[5] however, has recorded a remarkable instance in which the defect occurred in five generations of one family, there being thirteen cases, and all females. This appears to be a remarkable exception to the rule.[6] Dr. Earle observed, that the power of accurately distinguishing colours varies at different times in the same person; and that it is not unfrequently connected with, or accompanied by, a defect in the power of discriminating musical tones.[7]

The opinions of philosophers have varied regarding the cause of this singular defect in eyes otherwise sound, and capable of performing every other function of vision in the most delicate and accurate manner. By some, it has been presumed to arise from a deficiency in the visual organ; and by such as consider the ear to be defective in function in those that are incapable of appreciating musical tones, this deficiency in the eye is conceived to be of an analogous nature; and the

[1] Elements of the Philosophy of the Human Mind, ch. iii.

[2] Manchester Memoirs, v. 28.

[3] Proceedings of the American Philosophical Society for August 21, 1840; and in Lawrence, Treatise on Diseases of the Eye, Amer. edit., p. 637, Philad., 1855.

[4] American Journal of the Medical Sciences, April, 1845, p. 346.

[5] Annales d'Oculistique, i. 417.

[6] W. White Cooper, art. Vision, in Cyclop. of Anat. and Phys., iv. 1454, Lond., 1852.

[7] For many such cases see W. White Cooper, op. cit.; Hays, in Lawrence, op. cit.; and Mackenzie, Practical Treatise on the Diseases of the Eye, Amer. edit. by Dr. A. Hewson, p. 881, Philad., 1855.

analogy is farther exhibited by the facts, just mentioned, observed by Dr. Earle. "In the sense of vision," says Dr. Brown,[1] "there is a species of defect very analogous to the want of musical ear,—a defect which consists in the difficulty, or rather the incapacity, of distinguishing some colours from each other—and colours which, to general observers, seem of a very opposite kind. As the want of musical ear implies no general defect of mere quickness of hearing, this visual defect, in like manner, is to be found in persons who are yet capable of distinguishing, with perfect accuracy, the form, and the greater or less brilliancy of the coloured object; and I may remark, too, in confirmation of the opinion, that the want of musical tone depends on causes not mental but organic, that in this analogous case some attempts, not absolutely unsuccessful, have been made to explain the apparent confusion of colours by certain peculiarities of the external organ of sight."

Dr. Dalton, who believed the affection to be seated in the physical part of the organ, has endeavoured to explain his own case, by supposing, that the vitreous humour is *blue*, and therefore absorbs a great portion of the red and other least refrangible rays; and Sir David Brewster, in the "Library of Useful Knowledge,"[2] appears to think that it may depend upon a want of sensibility in the retinæ, similar to that observed in the ears of those who are incapable of hearing notes above a certain pitch; but as this view is not contained in his more recent "Treatise on Optics," it is probably no longer considered by him to be satisfactory.

The defect in question—difficult as it is to comprehend—has always appeared to the author to be entirely cerebral, and to strikingly resemble, as Dr. Brown has suggested, the "want of musical ear." As we have already endeavoured to establish, that the latter is dependent upon a defective mental appreciation, the parity of the two cases will, of course, compel us to refer the visual defect, or the want of the "faculty of colouring," to the same cause. It has been remarked, that the eye in these cases exercises its function perfectly as regards the form and position of objects, and the degree of illumination of their different portions. The only defect is in the conception of colour. The nerve of sight is probably accurately impressed, and the deficiency is in the part of the brain whither the impression is conveyed, and where perception is effected, which is incapable of accurately appreciating those differences between rays, on which their colour rests; and this is the view taken of it by one of the most eminent philosophers of the present day, Sir J. F. W. Herschel.[3]

The *mediate* or *auxiliary* functions of vision are numerous; hence, the elevated rank that has been assigned to it. By it, we are capable of judging, to a certain extent, of the direction, position, magnitude, distance, surface, and motion of bodies. Metaphysicians have differed greatly in their views on this subject; the majority believing, that,

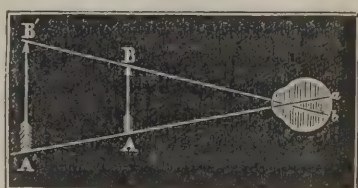
[1] Lectures on the Philosophy of the Human Mind, vol. i., Boston, 1826.
[2] Natural Philosophy, vol. i., Optics, p. 50, Lond., 1829.
[3] Encyclopædia Metropolitana, art. Light. See, on all this subject, W. White Cooper, op. cit.

without the sense of touch, the eye is incapable of forming any accurate judgment on these points; others, that the sense of touch is no farther necessary than as an auxiliary; and that a correct appreciation could be formed by sight alone. The few remarks that may be necessary on this subject will be deferred until the physical and other circumstances which enable us to judge of distance, &c., have been canvassed.

The *direction* or *position* of objects has already been considered, so far as regards the inverted image formed by them on the retina. The errors that arise on this point are by no means numerous, and seldom give rise to much inconvenience; yet, whenever the luminous cone meets with reflection or refraction before reaching the eye, the retina conveys erroneous information to the sensorium, and we experience an *optical illusion.*

To ascertain the *magnitude*, *distance*, and *surface* of bodies, we are obliged to take into consideration several circumstances connected with the appearance of the object,—such as its apparent size; the intensity of light, shade, and colour; the convergence of the axes of the eyes; the size or position of intervening objects, &c. Porterfield[1] enumerates six methods, which are employed in appreciating distance—1. The apparent magnitude of objects; 2. The vivacity of their colours; 3. The distinction of their smaller parts; 4. The necessary conformation of the eyes for seeing distinctly at different distances; 5. The direction of their axes; and 6. The interposition of objects. Dr. Brown[2] reduces them to three—1. The difference of the affections of the optic nerve; 2. The different affections of the muscles employed in varying the refracting power of each eye, according to the distance of objects, and in producing that particular inclination of the axes of the two eyes which directs them both equally on a particular object; and 3. The previous knowledge of the distance of other objects, "which form, with that we are considering, a part of one compound perception." Lastly, Dr. Arnott[3] enumerates four modes by which this is effected—1. The space and place occupied by objects in the field of view, measured by what is termed the *visual angle.* 2. The intensity of light, shade, and colour. 3. The divergence of the rays of light—and 4. The convergence of the axes of the eyes. This enumeration may be adopted with some slight modification. The circumstances, in our opinion, to be considered, are:—

Fig. 311.



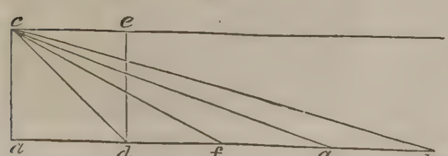
Visual Angle.

1. The *visual angle*, or that formed by two lines, which shave the extremities of an object and cross at the centre of the crystalline; so that the *visual angle*, subtended by the object, as A B, Fig. 311, is exactly equal to that subtended by its image *a b* on the retina. It is obvious, from this figure, that if all objects were equidistant from the eye, and of the same magnitude, they would subtend the same angle; and if not of the same magnitude, the difference would

[1] A Treatise on the Eye, ii. 409, London, 1759.
[2] Lectures on the Philosophy of the Human Mind, vol. i., Boston, 1826.
[3] Elements of Physics, new Amer. edit., p. 383, Philad., 1841.

be accurately indicated by the difference of the visual angles subtended by them. The two arrows, however, which are of different sizes, subtend the same visual angle, and are alike represented on the retina by the image *a b*. It is clear, then, that the visual angle does not give us a correct idea of the relative magnitudes of bodies, unless we are acquainted with their respective distances from the eye; and, conversely, we cannot judge accurately of their distances, without being aware of their magnitudes. A man on horseback, when near us, subtends a certain visual angle; but, as he recedes from us, the angle becomes less and less; yet we always judge accurately of his size, because aware of it by experience; but if objects are at a great distance, so as not to admit of their being compared with nearer by simple vision, we are in a constant state of illusion,—irresistibly believing, that they are much smaller than they really are. This is the case with the heavenly bodies. The head of a pin held close to the eye subtends as large a visual angle as the planet Jupiter, which is one thousand two hundred and eighty-one times bigger than this earth, and is eighty-six thousand miles in diameter. In like manner, a five-cent piece, held at some distance from the eye, shuts off the sun, although its diameter is eight hundred and eighty-eight thousand miles. The sun and moon, again, by subtending nearly the same visual angle, appear to us of nearly the same size; and the illusion persists in spite of our being aware of the mathematical accuracy, with which it has been determined, that the former is ninety-six millions of miles from us, and the latter only two hundred and forty thousand. The visual angle, again subtended by an object, differs greatly according to the position of the object. A sphere has the same appearance or bulk, when held at a certain distance from the eye, whatever may be the position in which it is viewed; and, accordingly, the visual angle, subtended by it, is always identical. Not so, however, with an oval. If held, so that the rays from one of its ends shall impress the eye, it will occasion a circular image, and subtend a much smaller angle than if viewed sideways, when the image will be elliptical or oval. The same thing must occur with every object, whose longitudinal and transverse diameters differ. It is obvious, that if any such object be held in a sloping position towards the eye, it will appear more or less shortened; in the same manner as the slope of a mountain or inclined plane would appear much greater, if placed perpendicularly before the eye. This appearance is what is called *foreshortening;* and it may be elucidated by the following figure. Suppose a man to be standing on a level plain, with his eye at *c* (Fig. 312), looking down on the plain. The portion of the surface *a d*, which is next to him, will be seen without any foreshortening; but if we suppose him to regard successively the portions *d f*, *f g*, and *g b* of the plain, the angle, subtended by each portion, will diminish; so that if the angle *a c d* be 45°, *d c f* will be 18°, *f c g* 8°, and so on; until, at length, the

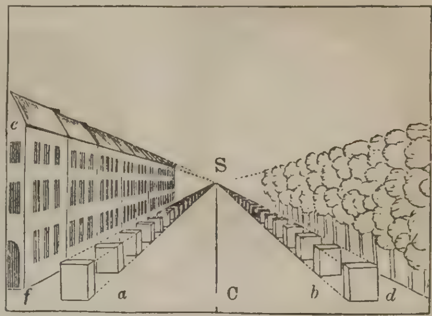
Fig. 312.



Foreshortening.

obliquity will be so great, that the angle becomes inappreciable. This is the cause why, if we look obliquely upon a long avenue of trees, we are unable to see the intervals between the farthest in the series; although that between the nearest to us may be readily distinguished. In all paintings, of animals especially, the principle of foreshortening has to be rigidly attended to; and it is owing to a neglect of this that we see such numerous distorted representations—of the human figure especially. It has been already stated, that objects appear smaller according to their distance; hence, the houses of a street, or the trees of an avenue, that are nearest to us, or in the foreground, form the largest images on the retina, and there is a gradual diminution, so that, if we could imagine lines to be drawn along the tops and bottoms of the objects, and to be sufficiently prolonged, they would appear to meet in a point, as in Fig. 313.

Fig. 313.



Perspective.

The art which traces objects, with their various degrees of apparent diminution on account of distance, and of foreshortening on account of obliquity of position, is called *perspective.*

2. *The intensity of light, shade, and colour.*—It has been shown, that the intensity of light diminishes rapidly, according to the distance of the body from which it emanates; so that it is only one-fourth as powerful when doubly distant, one-sixteenth when quadruply distant, and so on. This fact is early recognised; and the mind avails itself of it to judge, with much accuracy, of relative distances. It is, however, a pregnant source of optical illusions. In a bright sunshine, mountains appear much nearer to us than when seen through the haze of our *Indian summer.*[1] In a row of lamps along a street, if one be more luminous than the rest, it seems to be the nearest; and, in the night, we incur the strangest errors in judging of the distance of a luminous body. The sky appears nearer to the earth directly above, than it does towards the horizon; because the light from above having to pass only through the atmosphere is but slightly obstructed, whilst a portion only of that, which has to pass through the dense heterogeneous air, near the surface of the earth, arrives at the eye. The upper part of the sky being, therefore, more luminous seems nearer; and, in the same manner, we explain, in part, why the sun and moon appear

[1] A delightful season, in the southern and western parts of North America more especially, generally occurring in October or November; and having nothing similar to it, so far as we are aware, in any other part of the globe. It is dependent upon some meteorological condition of the atmosphere, and occurs only when the wind is southerly, or from the warmer regions; disappearing immediately as soon as it veers to the north. By some, this phenomenon has been supposed to be caused by the large fires in the western prairies; but the warmth that attends the haze cannot be explained on this hypothesis, independently of other sufficient objections to it.

larger at rising and setting. In the marginal illustration we have a striking illustration of the difference in apparent magnitude of two circles of the same size; one of which reflects all the rays; and the other absorbs all. The different degree of activity of the retina in the two cases causes the white circle to be considered—as estimated by Professor Budge[1]—one-fifth larger.

Fig. 314.

Apparent magnitude.

The shade of bodies keeps pace with their intensity of light; and accordingly, the shadows of objects near us, are strongly defined;—whilst in the distance they become confused, and the light altogether so faint, that the eye at last sees an extent of distant blue mountain or plain,—"appearing bluish," says Dr. Arnott,[2] "because the transparent air, through which the light must pass, has a blue tinge, and because the quantity of light arriving through the great extent of air is insufficient to exhibit the detail." "The ridge called Blue Mountains," he adds, "in Australia, and another of the same name in America, and many others elsewhere, are not really blue, for they possess all the diversity of scenery, which the finest climates can give; but to the discoverer's eye, bent on them from a distance, they all at first appeared blue, and they have ever since retained the name." As regards the Blue Ridge of America, Dr. Arnott labours under misapprehension. Within a very few miles from the whole of this extensive chain, as well as from a distance, the blue tinge is perceptible, especially when the air is dense and clear, soon after the sun has descended behind it; so that the name is as appropriate in the vicinity as it was when "the discoverer's eye was bent on it from a distance."

It is obvious, that without the alternation of light and shade we should be unable to judge, by the eye, of the shape of bodies,—to distinguish a flat circle from a globe; or any of the prominences and depressions, that are every where observable. The universe would seem to be a flat surface, the outlines of which would not even be perceptible; and the only means of discriminating objects would be by their difference of colour. It is partly by attending to the varying intensity of light and shade, that the painter succeeds in representing the near as well as the distant objects in an extensive landscape: those in the foreground are made bold and distinct; whilst the remote prospect is made to become gradually less and less distinct, until it fades away in the distance. This part of his art is called *aerial perspective*.

3. *Convergence of the axes.*—When an object is situate at a moderate distance from us, we so direct the eyes, that if the axes were prolonged

[1] Memoranda der speciellen Physiologie des Menschen, 5te Auflage, S. 321, Weimar, 1853.

[2] Op. cit., p. 401.

they would meet at it. This angle, of course, varies inversely as the distance; so that if the axis be turned to a nearer object, the angle will be greater; if to one more distant, less. By this change in the direction of the axes the mind is capable of judging, to a certain extent, of near distances. A definite muscular effort is required for each particular case; and the difference in the volition necessary to effect it enables the brain to discriminate, precisely in the same manner as it judges of the height of a body, by the muscular action required to carry the axis from one extremity of the object to the other.[1] We have the most satisfactory evidence, that such convergence of the axes is indispensable for judging accurately of distance in near vision. If we fix a ring to a thread suspended from a beam, or attach it to a stand, and endeavour, with one eye closed, to pass a hook, fixed to the extremity of a rod four or five feet long, into the ring, we shall find it impracticable unless by accident or by touching the ring with the rod. The hook will generally be passed on the far or near side of the ring; but if we use both eyes, we can readily succeed. They, however, whose eyes are of unequal power, cannot succeed with both eyes. This is shown by the difficulty experienced by those who have lost an eye. M. Magendie[2] says it sometimes takes a year, before they can form an accurate judgment of the distance of objects placed near the eye. The author has known one or two interesting examples, in which the power was never regained; notwithstanding every endeavour to train the remaining organ.

It need scarcely be said, that the convergence of the axes is no guide to us in estimating objects, which are at such a distance, that the axes are nearly parallel,—as the sun and moon, or any of the celestial luminaries.

4. *Interposition of known objects.*—Another mode of estimating the magnitude or distance of objects is by a previous knowledge of the magnitude or distance of interposed or neighbouring objects; and if no such objects intervene, the judgment we form is apt to be inaccurate. This is the reason why we are so deceived as to the extent of an unvaried plain or the distance at which a ship on the ocean may be from us: it is also another cause why the sky appears to us to be nearer at the zenith than it is at the horizon. The artist avails himself of this means of judging of magnitude in his representations of colossal species of the animal or vegetable kingdom, or of the works of human labour and ingenuity,—by placing a well-known object alongside of them as a standard of comparison. Thus, the representation of an elephant or a giraffe might convey but imperfect notions of its size to the mind, without that of its keeper being added as a corrective.

It is in consequence of the interposition of numerous objects, that we are able to judge more accurately of the size and distance of those that are on the same level with us, than when they are either much above or much below us. The size and distance of a man on horseback are easily recognised by the methods already mentioned, when he is riding before us on a dreary plain; the man and horse appearing more diminutive, but, being seen in their usual position, they serve as mutual

[1] Sir C. Bell, in Philos. Transact. for 1833. [2] Précis, &c., i. 88.

sources of comparison. When, however, the same individual is viewed from an elevated height, his apparent magnitude, like that of the objects around him, is strikingly less than the reality. Beautifully and accurately is this effect depicted by the great dramatist:—

"How fearful
And dizzy 'tis to cast one's eye so low!
The crows and choughs, that wing the midway air,
Show scarce so gross as beetles. Half way down
Hangs one that gathers samphire; dreadful trade!
Methinks he seems no bigger than his head.
The fishermen that walk upon the beach,
Appear like mice; and yon tall anchoring bark,
Diminish'd to her cock; her cock a buoy
Almost too small for sight." KING LEAR.

The apparent diminution in the size of objects seen from a height is not to be wholly explained by the foreshortening, which deprives us of our usual modes of judging. It is partly owing to the absence of intervening bodies; and still more perhaps to our not being accustomed to view objects so circumstanced. Similar remarks apply to our estimates of the size and distance of objects placed considerably above us. A cross, at the summit of a lofty steeple, does not appear more than one-fourth of its real size, making allowance for the probable distance; yet a singular anomaly occurs here:—the steeple itself seems taller than it really is; and every one supposes that it would extend much farther along the ground, if prostrated, than it would in reality. The truth, however, is, that if the steeple were laid along the ground, unsurrounded by objects to enable us to form an accurate judgment, it would appear to be much shorter than when erect, on the principles of foreshortening already explained. The cause of this small apparent magnitude of the cross and upper part of the steeple is, that they are viewed without any surrounding objects to compare with them: they, therefore, seem to be smaller than they are; and, seeming smaller, the mind irresistibly refers them to a greater distance. For these reasons, then, it becomes necessary, that figures, placed on lofty columns, should be of colossal magnitude.

It is owing partly to the intervention of bodies, that the sun and moon appear to us of greater dimensions, when rising or setting, although the visual angle, subtended by them, may be the same. "The sun and moon," says Dr. Arnott,[1] "in appearance from this earth are nearly of the same size, viz.:—each occupying in the field of view about the half of a degree, or as much as is occupied by a circle of a foot in diameter, when held one hundred and twenty-five feet from the eye—which circle, therefore, at that distance, and at any time, would just hide either of them. Now, when a man sees the rising moon apparently filling up the end of a street, which he knows to be one hundred feet wide, he very naturally believes, that the moon then subtends a greater angle than usual, until the reflection occurs to him, that he is using, as a measure, a street known, indeed, to be one hundred feet wide, but of which the part concerned, owing to its distance, occupies in his eye a very small space. The width of the street near him may occupy sixty degrees in his field of view, and he might see from between the houses

[1] Op. citat.

many broad constellations instead of the moon only; but the width of the street afar off may not occupy, in the same field of view, the twentieth part of a degree, and the moon, which always occupies half a degree, will there appear comparatively large. The kind of illusion, now spoken of, is yet more remarkable, when the moon is seen rising near still larger known objects—for instance, beyond a town or a hill which then appears within a luminous circle."

Such are the chief methods by which we form our judgment of the distance and magnitude of bodies;—1st, by the visual angle—2dly, by the intensity of light, shade, and colour—3dly, by the convergence of the axes of the eyes—and 4thly, by the interposition of known objects.

The eye also enables us to appreciate the *motion* of bodies. This it does by the movement of their images upon the retina; by the variation in the size of the image; and by the altered direction of the light in reaching the eye. If a body be projected with great force and rapidity, we are incapable of perceiving it;—as in the case of a shot fired from a gun, especially when near us. But if it be projected from a distance, as the field of view is very extensive, it is more easy to perceive it. The bombs, sent from an enemy's encampment, in the darkness of night, can be seen far in the air for some time before they fall; and afford objects for interesting speculation regarding their probable destination.

To form an accurate estimation of the motion of a body, we must be ourselves still. When sailing on a river, the objects, that are stationary on the banks, appear to be moving; whilst the boat, which is in motion, seems to be at rest. Bodies, that are moving in a straight line to or from us, scarcely appear to be in motion. In such cases, the only mode we have of detecting their motion is by the gradual increase in their size and illumination when they approach us; and the converse, when they are receding from us. If at a distance, and the visual angle between the extreme points of observation be very small, the motion of an object will likewise appear extremely slow; hence the difference between a carriage dashing past us in the street, and the same object viewed from a lofty column. A balloon may be moving along at the rate of nearly one hundred miles per hour; yet, except for its gradual diminution in size and intensity of light, it may appear to be at rest; and, when bodies are extremely remote from us, however astonishing may be their velocity, it can scarcely be detected. Thus, the moon revolves round the earth at the rate of between thirty and forty miles a minute—above forty times swifter than the fleetest horse; yet her motion, during any one moment, completely escapes detection; and the remark applies still more forcibly to those luminaries, which are at a yet greater distance from the earth. These are cases in which the body moves with excessive velocity, yet the image on the eye is almost stationary; but there are others in which the *real* motion is extremely slow and cannot be at all observed; as that of the hour-hand of a clock or watch.

It will be obvious, from all the remarks that have been made regarding the information derived by the mind from the sense of sight, that a strictly intellectual process has to be executed, without which no judgment can be formed; and that nothing can be more erroneous than the notion, at one time prevalent, that the method by which we judge of distance, figure, &c., is instinctive or dependent upon an original "law

of the constitution," and totally independent of any knowledge gained through the medium of the external senses. It has already been remarked, that metaphysicians may be considered as divided into those, who believe that, without the sense of touch, the eye would be incapable of forming any accurate judgment on these points;—and those who think, that the sense of touch is no farther necessary than as an auxiliary, and that a correct appreciation may be formed by sight alone. Messrs. Molyneux,[1] Berkeley,[2] Condillac,[3] &c., support the former view; MM. Gall,[4] Adelon,[5] &c., the latter.

Of the precise condition of the visual perception during early infancy, we are of course entirely ignorant. So far as our own recollections would carry us back, we have always been able to form a correct judgment of magnitude, distance, and figure. Observation, however, of the habitudes of infants would seem to show, that their appreciation of these points—especially of distance—is singularly unprecise; but whether this be owing to the sense not yet having received a sufficient degree of assistance from touch, or from want of the necessary developement in the structure or functions of the eyeball or its accessory parts, we are precluded from judging. The only succedaneum is the information to be obtained from those who have been blind from birth, and have been restored to sight by a surgical operation, regarding their visual sensations. Although in the numerous operations of this kind, which have been performed, it might seem, that cases must have frequently occurred for examining into this question, such is not the fact; and metaphysicians and physiologists have generally founded their observations on the well known case described by Mr. Cheselden.[6] The subject of this was a young gentleman, who was born blind, or lost his sight so early, that he had no remembrance of ever having seen; and was "couched,"—so says Cheselden,—"between thirteen and fourteen years of age." M. Magendie[7] affirms, that there is every reason to believe that the operation was not for cataract, but consisted in the incision of the pupillary membrane. It need hardly be remarked, that Cheselden must be the best possible authority on this subject. "When he first saw," says Cheselden, "he was so far from making any judgment about distances, that he thought all objects whatever touched his eyes (as he expressed it), as what he felt did his skin, and thought no objects so agreeable as those which were smooth and regular, though he could form no judgment of their shape, or guess what it was in any object that was pleasing to him. He knew not the shape of any thing, nor any one thing from another, however different in shape or magnitude; but upon being told what things were, whose form he before knew from feeling, he would carefully observe, that he might know them again; but having too many objects to learn at once, he forgot many of them; and (as he said), at first he learned to know, and again forgot a thousand things in a day. At first he could bear but very little light, and the things he saw he thought

[1] Locke's Essay on the Human Understanding, book ii. chap. 9.

[2] Essay on Vision, 2d edit., Dublin, 1709. [3] Traité des Sensations, Part i.

[4] Sur les Fonctions du Cerveau, i. 80, Paris, 1825.

[5] Physiologie de l'Homme, edit. cit., i. 466.

[6] Philosophical Transactions, No. 402, p. 477, for 1728; and Anatomy of the Human Body, 13th edit., Lond., 1792.

[7] Précis, &c., i. 95.

extremely large; but, upon seeing things larger, those first seen he conceived less, never being able to imagine any lines beyond the bounds he saw: the room he was in, he said, he knew to be but part of the house, yet he could not conceive that the whole house could look bigger."

A much more interesting case, in many respects, than this, which has always appeared to us too poetical, was laid before the Royal Society of London, in 1826, by Dr. Wardrop.[1] It was that of a lady born blind, who received sight at the age of forty-six, by the formation of an artificial pupil. During the first months of her infancy, this lady was observed to have something peculiar in the appearance of her eyes; and, when about six months old, a Parisian oculist operated on both eyes, with the effect of complete destruction of the one, and not the slightest improvement of the other. From this time, she continued totally blind, being merely able to distinguish a very light from a very dark room, but without the power of perceiving even the situation of the window through which the light entered; although in sunshine, or bright moonlight, she knew its direction: she was, therefore, in greater darkness than the boy in Cheselden's case, who knew black, white, and scarlet, apart from each other; and, when in a good light, had that degree of sight, which usually exists in an eye affected with cataract; whilst in this lady the pupil was completely shut up, so that no light could reach the retina, except such rays as could pass through the substance of the iris. After a third operation had been performed for the formation of an artificial pupil, she returned from Dr. Wardrop's house in a carriage, with her eyes covered by only a loose piece of silk. The first thing she noticed was a hackney-coach passing by, when she exclaimed, "What is that large thing that has passed by us?" In the course of the evening she requested her brother to show her his watch, when she looked at it a considerable time, holding it close to her eye. "She was asked what she saw, and she said there was a dark and a bright side; she pointed to the hour of twelve and smiled. Her brother asked her if she saw anything more; she replied yes, and pointed to the hour of six, and to the hands of the watch. She then looked at the chain and seals, and observed that one of the seals was bright, which was the case, being a solid piece of rock crystal." On the third day, she observed the doors on the opposite side of the street, and asked if they were red. They were of an oak colour. In the evening she looked at her brother's face, and said she saw his nose; he asked her to touch it, which she did: he then slipped a handkerchief over his face, and asked her to look again, when she playfully pulled it off, and asked, "What is that?" On the thirteenth day, she walked out with her brother in the streets of London, distinctly distinguishing the street from the foot pavement, and stepping from one to the other, like a person accustomed to the use of her eyes.

"Eighteen days after the last operation," says Dr. Wardrop, "I attempted to ascertain, by a few experiments, her precise notions of the colour, size, and forms, positions, motions, and distances of external objects. As she could only see with one eye, nothing could be ascertained respecting the question of double vision. She evidently saw

[1] Philosoph. Transact., 1826, p. 529.

the difference of colours; that is, she received and was sensible of different impressions from different colours. When pieces of paper, one and a half inch square, differently coloured, were presented to her, she not only distinguished them at once from one another, but gave a decided preference to some colours, liking yellow most, and then pale pink. It may be here mentioned, that, when desirous of examining an object, she had considerable difficulty in directing her eye to it, and finding out its position, moving her hand as well as her eye in various directions, as a person, when blindfolded or in the dark, gropes with his hand for what he wishes to touch. She also distinguished a large from a small object, when they were both held up before her for comparison. She said she saw different forms in various objects, which were shown to her. On asking what she meant by different forms, such as long, round, and square, and desiring her to draw with her finger those forms on her other hand, and then presenting to her eye the respective forms, she pointed to them exactly; she not only distinguished small from large objects, but knew what was meant by above and below; to prove which, a figure drawn with ink was placed before her eye, having one end broad and the other narrow, and she saw the positions as they really were, and not inverted [!!]. She could also perceive motions; for when a glass of water was placed on the table before her, on approaching her hand near it, it was moved quickly to a greater distance, upon which she immediately said, 'You move it; you take it away.' She seemed to have the greatest difficulty in finding out the distance of any object; for, when an object was held close to her eye, she would search for it by stretching her hand far beyond its position, while on other occasions she groped close to her own face for a thing far remote from her."

The particulars of this case have been given at some length, inasmuch as they are regarded by Dr. Bostock[1]—and apparently by Dr. Wardrop himself—as strikingly confirmatory of those of Cheselden, than which we cannot imagine anything more dissimilar. It will have been noticed, that, from the very first after the reception of sight, she formed an imperfect judgment of objects, and even of distances, although she was devoid of the elements necessary for arriving at an accurate estimate of the latter,—the sight of both eyes. This was, doubtless, the chief cause of that groping for objects described by Dr. Wardrop. Of forms, too, she must have had at least an imperfect notion, for we find, that on the thirteenth day after the operation, she stepped from the elevated foot-pavement to the street, "like a person accustomed to the use of her eyes."

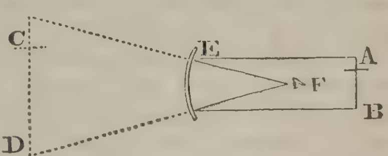
The case is, we think, greatly in favour of the view, that the sight does not require much education to judge with tolerable accuracy of the position, magnitude, distance, surface, and motion of bodies; and that, by a combination of the methods already pointed out, or of some of them, this imperfect knowledge is obtained without the aid of any of the other senses; but is of course acquired more easily and accurately with their assistance, especially with that of touch. What other

[1] Physiology, 3d edit., p. 703, Lond., 1836. See, also, the case of a gentleman born blind, and successfully operated on in the eighteenth year of his age, by Dr. J. C. Franz, in Proceedings of the Royal Society, 1840–41, No. 46.

than visual impressions could have communicated to the mind of Miss Biffin—whose case was referred to under another head—the accurate and minute information she possessed regarding the bodies surrounding her at all distances? Or how does the animal, immediately after birth, acquire its knowledge of distance? We observe the young of certain animals, immediately after they are extruded from the uterus, turn round and embrace the maternal teat; whilst others, as the partridge, follow the mother in a short time after they have burst the shell. The experience required for obtaining an imperfect knowledge of distance, shape, &c., must, therefore, be trifling; although an accurate acquaintance may demand numerous and careful comparisons. This first degree of knowledge is probably obtained, by comparing the visual angle with the intensity of light, shade, and colour,—the more accurate appreciation following the use of the other methods already described. That the convergence of the axes requires education is demonstrated by the case of the infant. It has been remarked, that the eyeballs harmonize instinctively in their parallel motions; but the convergence requires an effort of volition, and it is some time before it can be effected, which is probably the great cause of the mal-appreciation of near distances, that we notice in the infant; whilst it seems to exhibit its capability of judging more correctly of objects, that are somewhat more remote; and where less convergence, and consequently less muscular effort, is necessary.

The numerous *optical illusions*, which we have been led to describe in the progress of the preceding remarks, will render it necessary to refer to but few under this head. It has already been said, that we lay it down as a rule, that the progress of light to the eye is always in a straight line from the luminous object; and, accordingly, if the course of the rays be modified before they reach the organ, we fall into an optical illusion. Such modifications arise either from the reflection or refraction of the rays proceeding from the object that causes the sensation. By reflection of the rays, we experience the illusion caused by mirrors. A ray of light, K C, Fig. 259, falling upon a plane mirror, I J, is reflected back in the same line; but, as we have seen, the object does not appear to be at K, but at E. Again, a ray of light, proceeding obliquely from B, and impinging on a plane mirror at C, is reflected in the direction of C A; but to the eye at A, the object B appears to be at H, in the prolongation of the ray that reaches the eye.

Fig. 315.



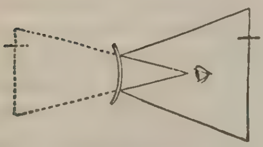
Concave Mirror.

If the mirror be concave, the object appears magnified, provided the light from the upper part of the object, as A B, Fig. 315, be reflected to an eye at F, and that from the lower part of the object meet the other at this point. To an eye so placed, the object appears magnified and seems to be at C D, or in the prolongation of the rays which fall upon the cornea. If the mirror be convex (Fig. 316), for like reasons, the cross will seem to be smaller.

The cornea constitutes a mirror of this class, in which we have an accurate miniature representation of objects.

Rays that are refracted in passing through different media, give rise to visual illusions. We have seen, that the ray from an object at F, Fig. 259, in the pool of water, I J, does not proceed into the air in the direction of F C O, but in that of the line F C A; and if we suppose the eye to be placed at A, the object will not be seen at F, but will appear to be at *f;* the pool will, consequently, appear shallower than it really is, by the space at which *f* is situate above the bottom. We can now understand why rivers appear less deep than they are, when viewed obliquely; and why the lower end of a pole, immersed in water, should, when seen obliquely, appear to be bent towards the surface. In shooting fish in the water, or in attempting to harpoon them, this source of error has to be corrected. Birds, too, that live upon the inhabitants of the water, have to learn, from experience, to obviate the optical illusion; or to descend perpendicularly upon their prey, in which direction, as we have seen, no refraction takes place. Similar remarks apply to fish that leap out of the streams to catch objects in the air. The *Chætodon rostratus*, about six or eight inches long, frequents the sea-shores in the East Indies: when it observes a fly sitting on the plants that grow in shallow water it swims to the distance of five or six feet, and then, with surprising dexterity, ejects out of its tubular mouth a single drop of water, which never fails to strike the fly into the sea, where it soon becomes its prey.[1] Hommel—a Dutch governor—put some of these fish into a tub of water, and pinned a fly on a stick within their reach. He daily saw the fish shoot at the fly, and with such dexterity, that they never failed to hit the mark.[2] Pallas describes the *Sciæna jaculatrix* as securing flies by a similar contrivance.[3]

Fig. 316.



Convex Mirror.

If the light, before reaching the eye, passes through bodies of a lenticular shape, it undergoes modifications, which have given occasion to the formation of useful instruments devised for modifying the sphere of vision. If the lens be double convex, the body, seen through it, appears larger than it is, from the illusion, so often referred to, that we always refer the object in the direction of the line that impinges upon the retina. The object, consequently, appears to be greatly augmented. (See Fig. 265.) For the same reasons an object seems smaller to the eye at A, Fig. 262, when viewed through a double concave lens. Again, if the light, before reaching the cornea, be made to pass through a diaphanous body, which is itself coloured, and consequently allows only the rays of its own colour to traverse it, the object is not seen of its proper colour, but of that of the transparent body.

An impression of light continues to affect the retina for some time

[1] Fleming's Philos. of Zoology, i. 195.
[2] Philos. Trans., liv. 89.
[3] Philos. Trans., lvi. 186; also, Mr. Sharon Turner's Sacred History of the World, Amer. edit., i. 205, New York, 1832.

after the impression has ceased, certainly for the sixth part of a second.[1] If, therefore, a live coal be whirled round, six or seven times in a second, it will seem to be a continuous circle of fire. It is owing to this circumstance, that meteors seem to form a line of light—as in the case of the falling star; and that the same impression is conveyed by a sky-rocket in its course through the air. We have an elucidation of the same fact in the instrument or toy—called, by Dr. Paris, *thaumatrope*—which consists of a circle, cut out of a card, and having two silken strings attached to opposite points of its diameter: by twisting these with the finger and thumb the card may be twirled round with considerable velocity. If we make on one side a black stripe as in the marginal figure 317, and on the other side one at right angles to it, Fig. 318, and cause the card to revolve rapidly, we shall see a cross.

Fig. 317.

Fig. 318.

Thaumatrope.

And if on one side of the card a chariot is drawn—and on the other a charioteer, and the card be twirled round six or seven times in a second, the charioteer will be seen in the chariot,—the duration of the impressions on the retina being such as to cause the figures, drawn on both sides of the card, to be seen at nearly the same time. The phantasmascope, phenakistiscope and anorthoscope, act upon similar principles.[2]

Ensmann[3] found, that the duration of the impression of colours is different; that of the yellow continuing longest, and next the white; that of the red being less, and of the blue least.

It is by accurate attention to various optical illusions, and to the laws of the animal economy on which they are founded, that many of them can be produced in the arts at pleasure. Painting is, in truth, little more than depicting on canvass the various optical errors, which we are habitually incurring.

To conclude:—the sense of sight differs materially in the scale of animals: in few is the organization more perfect or the function better executed than in man. Situate at the upper and anterior part of the body, the organ of vision is capable of directing its regards over a large extent of surface; the axes of the two organs can be converged upon objects in various situations, which cannot be done by many animals; and they are very movable under the domination of a muscular apparatus of admirable arrangement. Still, the eye is not as delicately

[1] D'Arcy, Mémoires de l'Académie des Sciences, p. 439, Paris, 1765; and Plateau, Annales de Chimie, &c., vol. lviii. p. 401.

[2] Müller, Principles of Physics and Meteorology, p. 310, Philad., 1848.

[3] Poggensdorff's Annalen, xci. 611, and Brit. and For. Med.-Chir. Rev., January, 1856, p. 236.

organized as in some animals, which are capable of seeing objects at a distance that would be totally beyond the reach of the visual powers of man.

Like the other senses, sight can be exerted *actively* and *passively;* hence the difference between simply *seeing*, and *looking*. In the latter, the eye is directed to the object by the proper muscles; and it is not improbable, that the nerve may be aroused to a more accurate and delicate reception of impressions, as we have reason for believing is the case in the other senses. Like them, it admits of great improvement by education. The painter, and the worker in colours are capable of nice discrimination, and detect the minutest shades of difference with great facility. In savage life, where the tracks or marks through the almost interminable forests, or over the pathless wilds, are the only guides, the greatest acuteness of vision is necessary; and, accordingly, we find the North American Indian, in this respect, eminently distinguished. The mariner, too, accustomed to look out for land, or for a hostile sail, detects it in the distant horizon long before it can be perceived by the landsman, and appreciates its distance and course with signal accuracy,—education, in this case, not only communicating to his eye facility in being impressed, but improving the intellectual process, by which the estimation of distances is arrived at.

F. ADDITIONAL SENSES.

The five senses constitute so many special nervous systems, each concerned in its appropriate function; and, although conveying ideas of the external world to the brain, and connected with that organ, they are to a certain extent independent of it. The generality of physiologists admit these five only; but some have suggested others, differing, in general, from the five, in having no organ at the surface of the body exclusively concerned in the function. Buffon regarded as a *sixth sense* the intense sensation experienced during the venereal act; but this can only be esteemed a peculiar variety of tact in the mucous membrane of the genital organs,—differing from ordinary tact in those parts, in requiring in both sexes a special condition of the membrane; and, in the male, one such, that the sperm, when excreted, shall make the necessary impression upon it; and, consequently, appertaining to both the external and internal sensations;—the state of the membrane being referable to the latter, and the effect of the contact of the sperm to the former. Some have spoken of a *sense of heat and cold:*—this has been referred to under the head of tact;—others of a *muscular sense*, by which we acquire a knowledge of the motions that muscular contractions give rise to, and learn to apportion the effort to the degree of effect to be produced. Animal magnetizers have suggested a sixth sense, to which man owes the capability of being acted upon by them: but this is supposititious, and the facts admit of a more ready and satisfactory explanation. A *sense of hunger* has been described as situate at the upper orifice of the stomach:—a *sense of thirst* in the œsophagus, and a *pneumatic sense* in the lungs; but these are rather internal sensations.

The German physiologists have suggested another sense, which they term *cœnæsthesis*, Gemeingefühl, Gemeinsinn, Körpergefühl, Lebenssinn, Individualitätssinn, and Selbstgefühl ("common

feeling, common sensation, bodily feeling, feeling of life, sense of life, sense of individuality, and self-feeling"). This is not seated in any particular part of the body, but over the whole system; hence termed "common." It is indicated by the lightness and buoyancy, which we occasionally experience, apparently without any adequate cause; as well as by a sense of lassitude and fatigue unconnected with muscular action or disease. To it, likewise, belong the involuntary shuddering, glow, and chilliness, experienced under like circumstances. It is manifestly one of the numerous internal sensations, felt by the frame, and every portion of it, according as they are in a perfect state of health, or labouring under irritation or oppression; but can scarcely be regarded as an additional or sixth sense.[1]

It has been supposed, that certain animals may possess other senses than the five. Of this we can have no positive evidence. We are devoid of the means of judging of their sensations; and if we meet with an additional organ, which seems adapted for such a purpose, we have nothing but conjecture to guide us. Under the sense of touch it was said, that the bat is found to be capable of avoiding obstacles placed in its way intentionally, when the eyes, nostrils, &c., have been closed up; and that it readily returns to the holes in caverns to which it is habituated. Spallanzani supposed that this was owing to its being possessed of a sixth sense. We have seen, that the circumstance is explicable by unusual delicacy of one of the external senses.

Again; the accuracy with which migratory animals return to their accustomed haunts has given rise to the notion of a *sense of locality.*

Quadrupeds, the ape not excepted, have two bones in the face, in addition to those found in man. These contain the roots of the dentes incisores, when such are present; but they also exist in animals that are destitute of teeth. They are termed *ossa intermaxillaria*, *ossa incisoria*, and *ossa labialia;* and are situate, as their names import, at the anterior part of the jaw, and between the ossa maxillaria or jaw bones. Jacobson[2] considers them to be an organ of sense, as they communicate with the exterior, and are largely supplied with vessels and nerves. Accordingly, this has been esteemed a sensitive apparatus, connected with the season of love in animals; and, by other naturalists, as a sense intermediate between those of taste and smell, and intended to guide the animal in the proper selection of food. It need hardly be said, that this is all imaginary.

M. Adelon,[3] it was remarked, makes two divisions of the external sensations:—those that convey information to the mind; and those that do not. The former have engaged attention; the latter will not occupy us long. They comprise but two—*itching* and *tickling*. Both of these occur in the skin and mucous membranes, and near the communication of the latter with the skin; or, in other words, near the termination of the outlets which they line. *Itching*, however, is not

[1] Purkinje, art. Cœnæsthesis, in Encycl. Wörterb. der Medicinisch. Wissenschaft., viii. 116, Berlin, 1832; and Müller's Elements of Physiology, by Baly, pt. v. p. 1087, London, 1839. See, also, E. H. Weber, art. Tastsinn und das Gemeingefühl, in Wagner's Handwörterbuch der Physiologie, 22ste Lieferung, S. 562, Braunschweig, 1849.

[2] Annales du Musée, xviii. 412.

[3] Physiologie de l'Homme, 2de édit., i. 481, Paris, 1829.

always an external sensation,—that is, not always caused by the contact of an external body. It frequently arises from an altered condition of the organic actions of the part in which it is experienced, as in cutaneous affections; in itching at the nose produced by irritation in the intestinal canal; itching of the glans penis in cases of calculi of the urinary bladder, &c.; but commonly the sensation is caused by an extraneous body, and we are irresistibly led to scratch, no matter how it may be caused. When it arises extraneously, it can generally be readily allayed; but, when dependent upon a morbid condition of the texture of the part, it becomes a true disease, and the source of much suffering. If the itching be accompanied with a feeling of motion, or of purring in the part, it is called *tingling*. This kind of purring often occurs without itching.

Tickling or *titillation* is always caused by the contact of some extraneous substance; and is therefore a true external sensation. Although occurring in the skin, and in the commencement or termination of the mucous membranes, all parts are not equally susceptible of it; and some,—as the lining membrane of the genital organs,—are only, or chiefly, so under special circumstances. The sides, palms of the hands, and soles of the feet, are the most sensitive in this respect; not, perhaps, because the nerves are more numerous in those parts, but because, owing to thinness or suppleness of skin, or to other inappreciable circumstances, they are more susceptible of this kind of excitation. We find, too, that individuals differ as much as the parts of the body do in this respect;—some being *not ticklish*, or incapable of being thrown into the spasm, which the act,—nay, even the threatening of the act,—produces in others. Cases are on record, in which prolonged titillation has caused general convulsions, and even death. Le Cat[1] terms it an hermaphroditic sensation, inasmuch as, whilst it excites laughter, it is insupportable; and, consequently, seems to be intermediate between pleasure and pain.

b. *Internal Sensations.*

The external sensations make us acquainted with the universe surrounding us; and convey to the mind a knowledge of every thing that can be, in any manner, inservient to our necessities. Such necessities have, however, to be suggested to the mind, before it reacts through the aid of the organs of prehension or otherwise on external bodies, and this is accomplished by the *internal* or *organic sensations*.

Without the intervention of an external cause, every organ of the body is capable of transmitting to the encephalon a number of different impressions, many of which impel the organs to acts that are necessary not only for the preservation of the individual and of the species, but also for the perfect developement of the faculties. Such are the sensations of hunger and thirst; the impulse that leads to the union of the sexes; and the feeling we have of the necessity for intermission in the exercise of the muscles, and the intellect. They have been divided into three species by some physiologists;—the *first* arousing, or giving impulse to, the action of organs, and warning the brain of the different

[1] Traité des Sens, Paris, 1767.

necessities of the system. They have been called *wants* or *instinctive desires.*[1] Such are hunger, thirst, the desire to evacuate the urine and fæces; that of respiration, the venereal appetite (*le génésique, sens génital*), *accouchement*, &c. They belong to those that arise, when it is necessary the organs should act.—The *second* occur during the action of organs. They are often obscure, but sometimes acute. Amongst these are the impressions accompanying the different excretions,—as of the sperm, urine, &c. (although, as we have seen, these partly belong to the external sensations); the impressions that warn us of our partial or general movements, of the progress of digestion, and of intellectual labours. The *last* succeed to the action of organs, especially when such action has been too long continued; hence the inward feeling of *fatigue* after too long exertion of the functions of the senses, of the intellectual and moral faculties, and of the organs of muscular motion; the *necessity of repose* after prolonged muscular exertion; and of *sleep*, to recruit the nervous system, and to fit it for the exertions it has to make during the waking condition.

The mode in which these sensations are effected is analogous to that of the external sensations. There is an *impression* on the part to which the sensation is referred; an action of *perception* accomplished by the encephalon; and one of *transmission*, executed by a nerve passing between the two. The last two actions are probably executed in the same manner as in the external sensations. The first, or the mode in which the impression is effected, and the character of the impression itself, are more obscure. In the external sensations, we can refer the impression to a known irritant,—special in some of the senses; more general in others. We know, that light impresses the retina;—aerial undulations the acoustic nerve, &c.; but, in the internal sensations or *sentiments*, as some of the French writers term them, the source of the irritation is in some modified action of the part itself, in the very tissue of the organ, and hence the result is said to be *organic*. In the internal sensation of hunger, for example, the impression is engendered in the organ,—how, we know not,—is thence conveyed to the brain, and the sensation is not effected until the latter has acted. The same may be said of all the internal sensations. They differ, in other respects, also, from the external. Whilst the latter may be entirely passive, or rendered active by volition, without either action being the cause of particular pleasure or inconvenience, the former are little influenced by volition. Constituting the wants—the instinctive desires—which impel to acts, that are necessary for the preservation and full developement of the individual and of the species, such independence is of course essential. On many of them, however, habit or accustomed volition has a certain degree of influence; and they can unquestionably be augmented or moderated by licentious indulgence or restraint. The influence of habit is exemplified by the regularity with which the appetite returns at stated intervals; and by the difference between that of the gourmand and of the temperate individual. It is most strikingly evidenced, however, in its influence over the

[1] Adelon, art. Besoins, in Dict. de Médecine, i. 367, Paris, 1821; and Physiologie de l'Homme, i. 482.

moral wants; which may even spring up from social indulgence, and hence are not instinctive or organic. We are every day compelled to witness the striking difference between the individual who practises restraint upon his wants, and the libertine, who, like the animals surrounding him, gives unbridled sway to his natural and acquired appetites.

All the internal sensations, when satisfied or responded to in moderation, communicate a feeling of pleasure; but if resisted, pain results. If hunger be prolonged, there is a general feeling of uneasiness, which rapidly abates after food is received into the stomach; but if satiety be produced, uneasiness follows; and this applies to all the appetites or wants. The special internal sensations will engage us, when the functions to which they belong fall under consideration. Like the external sensations, they must, of course, administer to the intellect, to an extent which will be seen hereafter. Their influence and nature were entirely neglected until of comparatively late years, when attention was directed to them chiefly through the labours of MM. Cabanis[1] and of Destutt-Tracy;[2] and they now form subjects for interesting speculation, with the metaphysician more especially.

The *morbid sensations* belong more particularly to pathology; a brief notice of them will consequently be all that is necessary here. They are comprised under the term *pain*. In its enlarged signification, this word, as is well known, means every uneasy or disagreeable sensation or moral affection:—thus including sadness, anger, terror, as well as the painful impressions felt in the extremities or trunks of the nerves. It is the latter only or *physical pain* that concerns us at present. Like every other sensation, although it may be referred exclusively to the part impressed, pain requires the intervention of the encephalon; for if the nerves, proceeding from a part to that organ, be cut, tied, compressed, or stupefied by narcotics; or if the action of the brain itself be blunted from any cause, as by the use of opium, ether, or chloroform, or by any compression, accidental or other, the sensation is no longer experienced. We can thus understand why pain is felt less during sleep; and the astonishing cases of resistance to pain, witnessed in the lunatic, and in religious or other enthusiasts who have been subjected to bodily torture. An opposite condition of the nervous system is the cause of the great sensibility to impressions in the nervous and hysterical.

It is obvious, that pain may be either an external or internal sensation, according as the cause of irritation is extraneous, or seated in the tissue of organs; and that it must vary considerably, both as regards the precise irritant, and the part affected; hence the difference between the pain caused by a burn, and that by a cutting instrument; and the immense variety of pains to which the human frame is subject, and the attentive study of which is so indispensable to the pathologist.

So much for the sensations. These, we have seen, are innumerable, for each sense is capable of myriads of different impressions. We now

[1] Rapport du Physique et du Morale de l'Homme, tom. ii., Paris, 1802.
[2] Elémens d'Idéologie, 2de édit., Paris, 1804.

pass to the consideration of those functions that enable man—although worse provided with means of defence and offence than the beasts surrounding him, and possessing no covering to protect him from the summer's heat or the winter's cold—to provide himself means of defence; to render the animals around him subservient to his use; to cover his nakedness, and protect himself against atmospheric changes; to devise mechanical arts; to fathom the laws, that govern the bodies by which he is surrounded, and to establish himself undisputed master of the earth.

G. MENTAL FACULTIES.

The external senses convey to the brain the different impressions made upon them by surrounding bodies; but, of themselves, they would be unable to instruct the mind regarding the universe. It is necessary, that the brain should act before any perception of them can exist. The *mental faculties*, in other words, convert the impressions into ideas. The internal sensations, on the other hand, consist, as we have seen, of the numerous wants and appetites necessary for the preservation of the individual, and the species. In addition to these, man possesses another series of faculties, which influence his character and disposition, and direct his social existence: these are the *affective* or *emotive faculties* or *faculties of the heart*. The study of these different mental and moral phenomena constitutes what has been called *psychology*,—so termed from an idea, that they are exclusively dependent upon the mind. The notion was, at one time, universal, and hence the appellation *metaphysician*, applied to such as were considered to proceed in their investigations beyond what was physical, material, or corporeal.

There is no subject, which has given occasion to so much excitement and controversy, as that of the connexion of the mental faculties with the encephalon. "It has unfortunately happened," says Dr. Bostock,[1] "that this subject, which is one of great interest and curiosity, has seldom been viewed with that philosophical spirit which should always direct our investigations, and by which alone we can expect to arrive at truth. It is admitted, that certain errors may be so interwoven with our accustomed associations on topics connected with morals and religion, as to render it doubtful, on some occasions, how far we ought to attempt their removal; but if this concession be made on the one hand, it is incumbent upon us, on the other, not to inflame the prejudices, which may exist on these topics, but to use our endeavours to correct all undue excitement, and thus to bring the mind into that tranquil state, which may enable it to receive truth without fear of injury." In such a spirit ought every discussion on the subject to be conducted; and in such a spirit will the few remarks that follow be offered.

The chief opinions, which have been indulged on the subject are,— 1st. That all the mental phenomena are immaterial, and the exclusive product of the mind. 2dly. That the sentient principle within us requires the intervention of an organ, through which it acts; in other

[1] Physiology, 3d edit., p. 744, Lond., 1836.

words, that mind is a principle superadded to organization; and 3dly. That where there is no organization there is no perception;—that wherever an organized structure, like the brain, exists, perception exists; that where the organization is imperfect, perception is imperfect; where the organization is sound and vigorous, perception is clear and vigorous; where it is impaired, perception is impaired; and that when organization ceases perception ceases also. This last view is *materialism.* It supposes, that a certain condition of matter is capable of thinking, reasoning, and understanding.

The doctrine,—that our intellectual and moral acts are superadded on organization, and that there is an organ concerned in their manifestation, is the one embraced by the generality of physiologists, and is most consistent with reason and analogy: it is but justice, however, to admit, that the views of those, who consider that a certain organization produces thought, are not deserving of the anathemas that have been directed against them on the score of irreligion. The charge would rather apply to those who doubt the power of Omnipotence to endow matter with such attributes. Were the mental and moral phenomena the exclusive products of the immaterial principle within us, they would hardly form subjects for physiological inquiry. That they are allied to organization is inferred for the following reasons. As they constitute so many functions, were they not provided with an organ or organs, they would form so many exceptions;—each of the sensations requiring an organ for its accomplishment. Again, our inward feeling induces us to refer them to a particular part of the frame; whilst thought appears to be effected within the head, the chief expressions of the passions are felt in the region of the heart or stomach. The faculties, moreover, are not the same in every individual. One man is a poet; another a mathematician; or one is benevolent, another cruel. If these faculties were the exclusive product of the mind, and not to be ascribed to diversity of organization, we should have to admit, that each individual has a different immaterial principle, and of course, that there must be as many kinds as there are individuals. Lastly. The faculties vary in the same individual according to circumstances. They are not the same in the child as in the adult; in the adult as in one advanced in life; in health as in disease; in waking as in sleep. During an attack of fever they become temporarily deranged; and are permanently so in all the varieties of insanity.[1] These facts are inexplicable under the doctrine, that they are the exclusive product of the mind or immaterial principle. An immaterial or spiritual principle ought to be immutable; yet we should have to suppose it capable of alteration; of growing with the growth of the body, and of becoming old with it; of being awake or asleep; sound or diseased. All these modifications must be caused by varying organization—of the brain in particular.

We may conclude, then, that the intellectual and moral faculties are not the exclusive product of the mind; that they require the intervention of an organ; and that this organ is the encephalon, or a part of

[1] Adelon, art. Encéphale, Dict. de Médecine, vol. vii.; and Physiologie de l'Homme, tom. i. edit. cit.

it—the cerebrum or brain—is announced by many circumstances. In the *first* place, they are phenomena of sensibility, and hence we should be disposed to refer them to a nervous organ; and, being the most elevated phenomena of the kind, to the highest of the nervous organs. In the *second* place, inward feeling impels us to refer them thither. We not only feel the process there, during meditation; but the sense of fatigue, which succeeds to hard study, is felt there likewise. The brain, again, must be in a state of integrity, otherwise the faculties are deranged; or, for the time, abolished. In fever, it becomes affected directly or indirectly, and the consequence is perversion of the intellect, in the form of delirium. If the organ be more permanently disordered, as by the pressure of an exostosis or tumour, or by some alteration in its structure or functions—less appreciable in its nature—insanity, in some form, may be the result.

In serious accidents to the encephalon, we observe the importance of the cerebrum to the proper exercise of the mental faculties clearly evinced. A man falls from a height, and fractures his skull. The consequence is depression of a portion of bone, which exerts a degree of compression upon the brain; or extravasation of blood from some of the encephalic vessels attended with similar results. From the moment of the infliction of the injury, the whole of the mental and moral manifestations are suspended, and do not return until the compressing cause is removed by the operation of the trephine. M. Richerand cites the case of a female, who had a portion of the brain accidentally exposed, and in whom it was found, that pressing on the organ completely suspended consciousness, which was not restored until the pressure was removed. A similar case occurred to Professor Wistar; and another is related by M. Lepelletier.[1] A patient of a M. Pierquien had an extensive caries of the os frontis, with perforation of the bone, which exposed the brain covered by its membranes. When she slept soundly, the organ sank down; when she dreamed, or spoke with feeling, turgescence and marked oscillations were perceptible; when the brain was pressed upon, she stopped in the middle of a sentence or a word; and when the pressure was removed, she resumed the conversation, without any recollection of the experiment to which she had been subjected. An important difference in the effect is, however, noticed in such cases according to the suddenness or tardiness with which the pressure is made. Whilst a sudden compression suspends the intellectual and moral manifestations, slow pressure, produced by the gradual formation of a tumour, may exist without exhibiting, in any manner, the evidences of its presence. Accordingly, the anatomist is at times surprised to discover such morbid formations in the brains of persons who have never laboured under any mental aberration.

A negative argument in favour of this function of the brain has been deduced from the fact, that disease of other portions of the body, even of the principal organs, may exist and pass on to a fatal termination, leaving those faculties almost unimpaired. Such is proverbially the case with phthisis pulmonalis; the subject of which may be

[1] Physiologie Médicale, &c., iii. 242, Paris, 1832.

flattering himself with hopes never to be realized, and devising schemes of future aggrandizement and pleasure until within a few hours of his dissolution.

The intellectual faculties differ in each individual, and vary materially with the sex. The brain is, in all these cases, equally different. Much may depend upon education; but it may, we think, be laid down as an incontrovertible position, that there is an original difference in the cerebral organization of the man of genius and of him who is less gifted; and that, as a general rule, in the former the brain is much more developed than in the latter. Whilst the brain of the man of intellect may measure from nineteen to twenty-two inches in circumference, that of the idiot frequently does not exceed thirteen, or is not greater than in the child one year old. It was an ancient observation, that a large developement of the anterior and superior parts of the head is a characteristic of genius; and, accordingly, we find, that all the statues of the sages and heroes of antiquity are represented with high and prominent foreheads. In the older poets, we meet with many evidences, that the height of the forehead was regarded as an index of the intellectual or moral character of the individual. Thus Shakspeare:—

> "We shall lose our time,
> And all be turn'd to barnacles, or to apes,
> With foreheads villanous low."
> CALIBAN, in "TEMPEST."—Act iv.

And again:—

> "Ay, but her forehead's low, and mine's as high."
> JULIA, in the "TWO GENTLEMEN OF VERONA."—Act iv.

The relation between the size of the head and the mental manifestations has, indeed, interwoven itself into our ordinary modes of speech. "Let it not be believed," says a distinguished writer,[1] "an affair of accident, that a head of considerable dimensions is found, from time to time, to coincide with a distinguished genius. Although the *amour propre* may object, the law is general. I have neither met in antiquity, nor in modern times a man of vast genius, whose head ought not to be ranged in the latter class, which I have just established, especially if attention be paid to the great developement of the forehead. Look at the busts and engravings of Homer, Socrates, Plato, Demosthenes, Pliny, Bacon, Sully, Galileo, Montaigne, Corneille, Racine, Bossuet, Newton, Leibnitz, Locke, Pascal, Boerhaave, Haller, Montesquieu, Voltaire, J. J. Rousseau, Franklin, Diderot, Stoll, Kant, Schiller, &c."

Yet we are not always accurate in estimating the size of the brain from the developement of the head. Dr. Sewall[2] has clearly shown, that skulls of the same dimensions, as measured by the craniometer, differ largely as to the quantity of cerebral substance, which they are capable of containing. With the assistance of Dr. Thomas P. Jones, of Washington, and of Professor Ruggles, of the Columbian College, he instituted various experiments. In the first series, he ascertained the volume of each skull, brain included: in the second series, the volume of the brain alone or the capacity of the cerebral cavity; and in order

[1] Gall, Sur les Fonctions du Cerveau, ii. 342, Paris, 1825.

[2] An Examination of Phrenology, in Two Lectures, 2d edit., p. 66, Boston, 1839.

to render the difference in capacity more obvious, the volume of each skull, brain included, was reduced to the dimensions of 70 fluidounces. The results of the experiments on five skulls, delineated in the plates of Dr. Sewall's work, were as follows:—

	Volume of Skull, Brain included.	Volume of Brain.
Plate II.	70 oz.	56·22 oz.
III.	do.	51·72
IV.	do.	46·21
V.	do.	34·79
VII.	do.	25·33

In two of these skulls, consequently, of the same external dimensions, there was a difference in the volume of brain of 31·89 oz. Dr. Sewall inferred from his observations, that no phrenologist, however experienced, can, by any inspection of the living head, ascertain whether a person has a skull of one inch or one-eighth of an inch in thickness; or whether he has 56·22 ounces of brain, or only 25·33 ounces.

To the view, that the mental capacity is in a ratio with the size of the brain, there must be numerous exceptions; for, independently of bulk, there may obviously be an organization productive of results, in which the largely developed organ may be greatly deficient. Size is only one of the elements of activity of an organ. "Whilst there is an evident connexion," says a recent writer,[1] "between a large *quantity* of cerebral matter, and a highly developed intellect, the *quality* of the mind and that of the brain-substance may also be supposed to have a close relation to each other. In great power of action a *large* muscle is needed, but for vigorous and well-adjusted muscular movement a certain *quality* of fibre is also necessary to give full scope to the nervous power. It is impossible to determine what the peculiarity in quality is; but some idea of the great influence which it may possess in the exercise of the two great vital forces, the *muscular* and *nervous*, may be gained from comparing the energy and action of a well-bred horse, with one of those which, in the language of the turf, shows little or no breeding. The actual amount of muscular or nervous fibre may be the same in both, or it may be less in the horse of good breeding than in the other, yet the former does his work, and endures fatigue better."

The difference between the *moral* of the male and the female is signal; and there is no less in the shape of the encephalon in the two sexes. Observation, not only by anatomists but by sculptors and painters, shows, that the superior and anterior parts of the brain are less developed in the female, whose forehead is, therefore, as a general rule, smaller; whilst the posterior are larger. In the system of Gall, the anterior and superior parts are considered to be connected with the intellectual manifestations, which are more active in man; whilst the posterior are concerned in the softer feelings, which predominate in the character of the female. The mental and moral faculties vary, also, in the same individual, according to age, health, and disease; and in the waking and sleeping state. In all these conditions, we have reason to believe the state of the encephalon is as various. The anatomist notices a manifest

[1] Todd and Bowman, The Physiological Anatomy and Physiology of Man, p. 262, Lond., 1845.

difference between its organization in the infant and in the adult or aged. Like the other organs of the body, it is gradually developed until the middle period of life; after which it decays with the rest of the frame. Our acquaintance with the minute organization of the body does not enable us to say on what changes these differences are dependent. We see them only in their results. By the minutest examination of the special nerves of sense we are incapable of saying, why one should appreciate the contact of sapid bodies, another that of light, &c. During sleep, again, in which the functions of the brain are more or less suspended, the condition of the organ is modified; and mania or delirium probably never occurs without the physical condition of the brain having undergone some change, directly or indirectly. It is true, that, on careful examination of the brains of the insane, it has often happened, that no morbid appearance has presented itself; but the same thing has occurred on inspecting those who have died of apoplexy or paralysis, in which not a doubt is entertained that the cause is seated in the encephalon, and that it consists in a physical alteration of its tissue. These are a few of the cases which make us sensible of the limited nature of our powers of observation. They by no means encourage, in the most sceptical, the belief, that the tissue of the organ is not implicated. The investigations of the morbid anatomist, consequently, afford us few data on which to form our opinions on this subject.

The effect of intoxicating substances is mainly exerted on the brain. When taken in moderation, all the faculties are excited; but if pushed too far, the intellectual and moral manifestations become perverted. This can only be through their action on the cerebral organ. We can thus understand how regimen may cause important modifications in the brain. Climate has probably a similar influence; hence the difference between the characters of different nations and races. The skull of the Mongol is different from that of the Kelto-Goth or of the Ethiopian; and the brain, as well as its functions, exhibits equal diversity.

Again, it has been argued, that the facts noticed in the animal kingdom are in favour of the brain being the organ concerned in the mental manifestations; that if each animal species has its own psychology, in each the encephalon has a special organization; and that in those which exhibit superior powers, the brain is found larger, and more complicated. To a great extent this is true. Nothing, indeed, seems more erroneous than the notion, that even sensibility to pain is equal in every variety of the animal creation. As we descend in the scale, the nervous system is found becoming less and less complicated; until ultimately it assumes the simplest *original* character, which laid the foundation for one of the divisions of Sir Charles Bell's system; and although it is impossible to change places with the animal, we have the strongest reasons for believing, that the sensibility diminishes as we descend; and that the feeling, expressed by the poet, that the beetle, which we tread upon—

> "In corporal sufferance finds a pang as great
> As when a giant dies"—

however humane it may be, is physiologically untrue. The phenomena in favour of this view which present themselves to the naturalist are

numerous and interesting; and afford signal evidence of creative wisdom in endowing the frames of those beings of the animal kingdom, that are most exposed to injury and torture, with a less sensible organization. The frog continues sitting, apparently unconcerned, for hours after it has been eviscerated; the tortoise walks about after having lost its head; and the divisions of the polypus, made by the knife, form so many distinct animals. Redi removed the whole of the brain of a common land tortoise: the eyes closed to open no more; but the animal walked as before,—groping, as it were, its way for want of vision. It lived nearly six months. All have noticed the independence of the parts of a wasp, after the head has been severed from the body. It will try to bite, and, for a considerable time, the abdomen will attempt to sting. An illustrative instance of the kind occurred to Dr. Harlan.[1] He cut off the head of a rattlesnake; and, grasping the part of the neck attached to the head with his finger and thumb, the head twisted itself violently, endeavouring to strike him with its fangs. A live rabbit was presented to the head, which immediately plunged its fangs deep into the animal; and when the tail of the snake was laid hold of, the headless neck was bent quickly round as if to strike the experimenter.

The experiments of Dr. Le Conte,[2] of Savannah, Georgia, and of Dr. Bennet Dowler,[3] of New Orleans, on the Alligator—*crocodilus lucius*—exhibit like results, and would lead to the inference, that in that animal, phenomena essentially resembling those, which in the upper classes of animals are referable to the encephalon, may be more diffused in their origin. In one experiment by the latter gentleman, and Dr. Young, aided by Mr. Barbot, the head of the animal, for more than an hour after decollation, exhibited that it possessed sensation, perception, vision, passion, and voluntary motion. "It saw its enemies; opened its mouth to bite at the proper time; and nictated when a foreign body approached the eye;" and for three or four hours the headless trunk, during extensive mutilations by two operators, "manifested, in a still higher degree, sensation, intelligence, definite, well-directed muscular actions. There was, as usual, a complete loss of progressive or forward motion. The test used to elicit sensation and voluntary movements were pinching, puncturing and burning. Its sensibility and motions appeared to be nearly as acute, quick and varied as in the unmutilated animal. The direction of the limbs was not such as could be deemed habitual, as in walking and swimming. Some of these motions are of difficult execution in the entire animal from its anatomical conformation, such as reaching up between the shoulders or hips to remove an irritant."

In another experiment performed in the presence of Drs. Cartwright, Smith, Nutt, Powell, Hire, Mr. Barbot, and Professor Forshey—in which decollation was practised with a dull hatchet, and, in consequence, the hemorrhage was not great, although considerable—Dr. Dowler carried the handle of a knife towards the eye, to ascertain whether it would wink; "whereupon the ferocious, separated head" sprang up from the

[1] Medical and Physical Researches, p. 503, Philad., 1835.
[2] New York Journal of Medicine, Nov., 1845, p. 335.
[3] Contributions to Physiology, New Orleans, 1849.

table with great force at him, passing very near his breast, which received several drops of blood; and then alighted upon the floor from six to eight feet distant from its original position. It missed him because he was standing at the side, and not in front of the head. "For about two hours,"—says Dr. Dowler—"the headless trunk exhibited such phenomena as are usually attributed to the brain,—namely, sensation, volition, and intelligential motion, as tested by the application of bits of ignited paper, wounds, and the like, whereupon the usual indicants of pain were elicited with great promptness and precision: it trembled, receded, rolled over, curved, placed its limbs accurately to the exact spot, and removed the offending cause. In certain places, this was exceedingly difficult, as on the spine between or near the shoulders or hips. It always used the limb the best adapted for the purpose. If the fire was too remote, as when applied to the tail, the whole body was thrown into the most favourable position for the purpose of reaching and removing the same. If the fire was placed on the table, in a position to annoy, yet without touching, the animal—as if endowed with sight—reached, and always accurately, to the exact spot, and either extinguished the fire or removed it. As upon former occasions, if the animal found that the fire was continued at the same spot, and that it could not remove it, which was sometimes the case, owing to continuous or repeated applications, and carefully manœuvring, it curved the body,—scratched violently, manœuvred skilfully, and then, as a last resort, rolled quite over, laterally, always *from*, never *towards* the fire and operator."

Still, the position, that in man and the upper classes of animals, the brain is the organ through which the mind acts in the production of the different mental and moral manifestations, can scarcely be contested.[1] Yet, amongst those who admit the accuracy of this conclusion, a difference of sentiment exists,—some conceiving that other organs participate in the function. To each of the known temperaments as many intellectual and moral dispositions have been ascribed. It has been affirmed, that if the brain be manifestly the organ of intellect the passions must be referred to the organs of internal or organic life; whilst others have regarded the brain as a great central apparatus for the reception and elaboration of the different impressions made upon the external senses;—thus conceiving the latter to be direct agents in the execution of the function, as well as the brain.

The influence of the temperaments upon the mental and bodily powers is much less invoked at the present day than it was of old. The ancients esteemed organized bodies to be an assemblage of elements, endowed with different qualities, but associated and combined so as to moderate and *temper* each other. Modern physiologists mean by temperament the reaction of the different organs of the body upon each other consistently with health; so that if one set or apparatus of organs predominates, the effect of such predominance may, it is conceived, be exerted on the whole economy. In the description of the temperaments in different authors we find a particular character of

[1] Gall, Sur les Fonctions du Cerveau, ii. 69, Paris, 1825; Adelon, art. Encéphale, Dict. de Médec., vii. 517; and Physiologie de l'Homme, ed. cit., i. 496.

intellectual and moral faculties assigned to each. The man of *sanguine* temperament is described as of ready conception, retentive memory, and lively imagination; inclined to pleasure, and generally of a good disposition; but inconstant and restless. He of the *bilious*, on the other hand, is said to be hasty, violent, ambitious, and self-willed; whilst the *lymphatic* temperament bestows feeble passions; cold imagination; tendency to idleness; and the *melancholic* disposes to dulness of conception, and to sadness and moroseness of disposition. M. Gall[1] has animadverted on this assignment of any intellectual or moral faculty to temperament. If we look abroad, he affirms, we find the exceptions more numerous than the rule itself; so numerous, indeed, as to preclude us from establishing any law on the subject. Moreover, the idiot, who possesses a temperament like other persons, has no intellectual faculties. The temperament, doubtless, influences the brain within certain limits, as it does other functions: this, he suggests, it probably does by impressing them with a character of energy or of languor, but without, in any respect, regulating the intellectual sphere of the individual.

Bichat,[2] again, maintained, that whilst the encephalon is evidently the seat of the intellectual functions, the organic nervous system, and, consequently, the different organs of nutrition, which are supplied by it, are the seat of emotions or passions. That distinguished physiologist, than whom, as M. Corvisart wrote to the First Consul, on announcing his death, "*personne en si peu de temps n'a fait tant de choses et aussi bien*,"[3] rests his views upon the following considerations:—1st. That while inward feeling induces us to refer intellectual acts to the brain, the passions are referred to the viscera of the thorax or abdomen. 2dly. That the effects of intellectual labour are referred to the encephalon, as indicated by redness and heat of face, and beating of the temporal arteries in violent mental contentions, &c.; and whilst the passions affect the organic functions, the heart is oppressed, and its pulsations are retarded or suspended; the respiration becomes hurried and interrupted; the digestion impeded or deranged, &c.; and 3dly. That whilst our gestures and language refer intellect to the encephalon, they refer emotions to the nutritive organs. If we wish to express any action of the mind, or are desirous of recalling something that has escaped the memory, the hand is carried to the head; and we are in the habit of designating a strong or weak intellect as a "strong or weak *head*;" or we say, that the possessor has "much or little brain." On the other hand, if desirous of depicting the passions, the hand is carried to the region of the stomach or heart; and the possessor of benevolent or uncharitable sentiments is said to have a good or a bad *heart*. Bichat properly adds, that this idea is not novel, inasmuch as the ancients conceived the seat of the passions to be in the epigastric centre;—that is, in the nervous plexuses situate in that region. He remarks that amidst the varieties presented by the passions, according to age, sex, temperament, idiosyncrasy, regimen, climate, and disease, there is always a ratio between them and the degree of predominance

[1] Op. citat., ii. 140. [2] Sur la Vie et la Mort, Part. i., Paris, 1806.
[3] Éloge de Xavier Bichat, par Miquel, p. 58, Paris, 1823.

of the different nutritive apparatuses; and he concludes with a deduction, which ought not to have been hazarded without full reflection,—that as the functions of the nutritive organs, in which he ranges the passions, are involuntary, and consequently uninfluenced by education, education can have no influence over the passions, and the *disposition* is consequently incapable of modification.

The answer of MM. Gall[1] and Adelon[2] to the views of Bichat appears to us to be irrefragable. How can we conceive, that viscera, whose functions are known, and which differ so much from each other, are agents of moral acts? The passions are sensorial phenomena, and like all phenomena of the kind, must be presumed to be seated in essentially nervous organs. Again;—when an injury befalls the brain, and the intellectual faculties are perverted or suspended by it, the same thing happens to the affective faculties; and if the viscera fulfil the high office assigned to them, why are not the passions manifested from early infancy, a period when the viscera are in existence and active? The argument of Bichat, that the phenomena which attend and follow the passions, are referable to the nutritive organs, is not absolute. The functions of animal life are frequently disturbed by the passions, as well as those of organic life. It is not uncommon for them to induce convulsions, mania, epilepsy, and other affections of the encephalon. The effect here, as M. Adelon remarks, is mistaken for the cause. The heart certainly beats more forcibly in anger, but the legs fail us in fear; and if we refer anger to the heart, we must, by parity of reasoning, refer fear to the legs. By reasoning of this kind, the passions might be referred to the whole system, as there is no part which does not suffer more or less during their violence. The error arises from our being impressed with the most prominent effect of the passion—the feeling accompanying it—and this is the cause of the gesture and the descriptive language, to which Bichat has given unnecessary weight in his argument. If, then, the views of Bichat regarding the seat of the passions be unfounded, the mischievous doctrine deduced from them—that they are irresistible, and cannot be modified by education—falls to the ground. His notion was, that the nutritive organs are the source of irritative irradiations, which compel the brain to form the determinations that constitute the passion, and to command the movements by which it is appeased or satisfied. A similar view is embraced by M. Broussais,[3] who, however, conceives, that the passions can be fomented and increased by attention, until they become predominant. Daily experience, indeed, exhibits the powerful effect produced on the passions by well-directed moral restraint. How many gratifying instances have we of persons, whose habitual indulgence of the lowest passions and propensities had rendered them outcasts from society, having become restored to their proper place by exerting due control over their vicious inclinations and habits! We can not only curb the expression of the passions, as we are constantly compelled to

[1] Op. citat., i. 94.

[2] Art. Encéph. (Physiol.) in Dict. de Méd., vii. 521, and Physiologie de l'Homme, edit. cit., i. 510.

[3] Examen des Doctrines Médicales, ii. 388, and Physiology applied to Pathology, Drs. Bell and La Roche's translation, p. 136, Philadelphia, 1832.

do in social intercourse; but even modify the internal susceptibility by well-directed habits of repression.

Lastly. Many physiologists have considered the brain as a great nervous centre for the reception and elaboration of different impressions conveyed thither by the external senses; and absolutely requiring such impressions for the mental manifestations. They consequently rank, amongst the conditions necessary for such manifestations, not only the brain which elaborates them, but the parts that convey to it the impressions or materials on which it has to act; and conceive, that a necessary connexion exists between these two orders of parts. The supporters of these opinions ascribe the differences observed in the intellectual and moral faculties of different persons as much to diversity in the number and character of the impressions as to differences in the encephalon itself. They do not all, however, agree as to the source of the impressions, which they conceive to be the *raw material* for the intellectual and moral acts. M. Condillac[1] and his school admit only one kind;—those proceeding from the external senses, which they term *external impressions*. M. Cabanis,[2] in addition to these, admits others proceeding from every organ in the body, which he terms *internal impressions*.

The school of Condillac set out with the maxim ascribed to Aristotle, "*nihil est in intellectu quod non prius fuerit in sensu*;" and they adopt, as an elucidation of their doctrine, the ingenious idea of Condillac—of a statue, devoid of all sensation, which is made to receive each of the five senses in succession; and which, he attempts to show, from the impressions received, may be able to develope gradually the different intellectual and moral faculties. All these, he affirms, are derived from impressions made on the external senses; and he considers the whole of human consciousness to be sensation variously transformed.

The views of Condillac have been largely embraced, with more or less modification; and, at the present day, many metaphysicians believe, that impressions on the senses are the necessary and exclusive materials for all intellectual acts. His case of the statue seems, however, to be by no means conclusive. It must, of course, be possessed of a centre for the reception of impressions made upon different senses, otherwise no perception could occur; and if we can suppose it possible for such a monstrous formation as a being totally devoid of external senses to exist; such a being must not only be defective in the nerves which, in the perfect animal, are destined to convey impressions to the brain, but probably in the cerebral or percipient part likewise. From defective cerebral conformation, therefore, the different mental phenomena might not be elicited.[3] If, however, we admit in such a case the possible existence of cerebral structure,—particularly of those portions that are especially concerned in the function of thought,—being properly organized, it appears to us, that certain mental or moral manifestations ought to exist. Of course, all knowledge of the universe would be precluded, because deprived of the *instruments* for obtaining such knowledge; but the brain would act as regarded the internal sensations. In order that such a being may live, he must be supplied with the neces-

[1] Traité des Sensations, i. 119.

[2] Rapport du Physique et du Moral de l'Homme, 4ème édit., par G. Pariset, Paris, 1824.

[3] Adelon, op. citat., i. 519.

sary nourishment; possess all those internal sensations or wants that are inseparably allied to organization; and must, consequently, feel the desires of hunger and thirst; but we have seen, that these sensations require the intervention of the brain as much as the external sensations. Supposing him, again, to survive the period of puberty, he must experience the instinctive changes, which occur at this period, and which must furnish impressions to the encephalon. In this assumed case, then, a certain degree of mental action might exist; and, under the supposition of a properly organized brain, ideas—limited, it is true, in consequence of the privation of the ordinary inlets of knowledge—might be formed; and memory, imagination, and judgment be compatible within certain limits.

The objections to the view, that the intellectual and moral sphere of man and animals is proportionate to the number and perfection of the external senses are overwhelming. Animals have the same number of senses as man, and, frequently, have them more perfect; yet in none is the mental sphere co-extensive. The idiot has the external senses as delicate as the man of genius, and often much more so; many of those of the greatest talents having the senses extremely obtuse. It has been already remarked, that the superiority of the human intellect has been referred entirely to the sense of touch, and to the happy organization of the human hand; but the case of Miss Biffin, and others, and that of the young artist cited by M. Magendie,[1] negative this presumption. The senses are important secondary instruments,—indispensable for accomplishing certain manifestations of the mind, but, in no way, determining its power.

The example of the deaf and dumb is illustrative of this matter.[2] If a child be born deaf, he is necessarily dumb; inasmuch as he is unable to hear those sounds which, by their combination, constitute language; and cannot therefore imitate them;—a connexion between the functions of hearing and speech, which was not well known to the ancients. For a length of time, these objects of compassionate interest were esteemed to be beyond the powers of any kind of intellectual culture, and were permitted to remain in a state of the most profound ignorance. The ingenuity of the scientific philanthropist has, however, devised modes of instruction, by which their mental power has been exhibited in the most gratifying manner, and in a way to prove, that the sense of hearing is not indispensable for great mental developement; but that its place may be supplied, to a great extent, by the proper exercise of others. The deaf and dumb, deprived of the advantages of spoken language, are compelled to have recourse to the only kind available to them,—that addressed to the eye. In this typical way, by a well-devised system of instruction they can be taught to preserve their ideas, and to multiply them, like the perfectly formed, by the spoken and written language,—without one or the other of which the human mind would have remained in perpetual infancy. Thus, the deaf and dumb have not only like ideas; but the same words to convey them to others.

Yet the deaf and dumb are not so much the objects of our commiseration as they who have been deprived, from birth or from early in-

[1] See vol. i. p. 695.

[2] Gall, op. cit., i. 119.

fancy, of both sight and hearing, and have thus been devoid of two of the most important inlets for the entrance of impressions from the surrounding world. In such case, it is obvious, they are shut out from all instruction, except what can be afforded by the senses of touch, smell, and taste; yet even here we have the strongest evidence of independent intellect. One of the most striking cases of the kind is that of the Scotch boy Mitchell, the object of much interest to Spurzheim and to Dugald Stewart,[1] both of whom have described his case in their writings. It is matter of uncertainty, whether either his deafness or blindness was total. The evidences of the sensation of hearing were, in a high degree, vague and unsatisfactory; but he gave more convincing proofs of the possession of partial vision. He could, for example, distinguish day from night; and, when quite young, amused himself by looking at the sun through crevices in the door, and by kindling a fire. At the age of twelve, the tympanum of each ear was perforated; but without any advantage. In his fourteenth year, the operation for cataract was performed on the right eye, after which he recognized more readily the presence of external objects; but never made use of sight to become acquainted with the qualities of bodies. Before and after this period, red, white, and yellow particularly attracted his attention. The senses, by which he judged of external bodies, were those of touch and smell. His desire to become acquainted with objects was great. He examined every thing he met with, and each action indicated reflection. In his infancy, he smelt at every one who approached him; and their odour determined his affection or aversion. He always recognized his own clothes by their smell; and refused to wear those which he found to belong to others. Bodily exercises, such as rolling down a small hill, turning topsy-turvy, floating wood or other objects on the river that passed his father's house; gathering round, smooth stones, laying them in a circle, and placing himself in the middle, or building houses with pieces of turf, &c., were a source of amusement to him. After the operation on his right eye, he could better distinguish objects. His countenance was very expressive; and his natural language not that of an idiot, but of an intelligent being. When hungry, he carried his hand to his mouth, and pointed to the cupboard where the provisions were kept; and, when he wished to lie down, reclined his head on one side upon his hand, as if he wished to lay it upon the pillow. He easily recollected the signification of signs that had been taught him; all of which were of course of the tactile kind. To make him comprehend the number of days before an event would happen, they bent his head as a sign that he would have to go to bed so many times. Satisfaction was expressed by patting him on the shoulder or arm; and discontent by a sharp blow. He was sensible of the caresses of his parents; and susceptible of different emotions—hatred, passion, malice, and the kindlier feelings. He was fond of dress, and had great fears of death, of the nature of which he had manifestly correct notions. Mitchell's case has been pregnant with interest to the

[1] Elements of the Philosophy of the Human Mind, &c.; Transactions of the Royal Society of Edinburgh, vol. vii.; and Dr. Gordon, ibid., vol. vi.; also, History of James Mitchell, a boy, born blind and deaf, by James Wardrop, London, 1813.

metaphysician; but it is not so elucidative as it would have been had the privation of the senses in question been total.

There is, in the American Asylum at Hartford in Connecticut, a being not less deserving of attention than Mitchell.[1] Her name is Julia Brace. She is the daughter of John and Rachel Brace, natives of Hartford, and was born in that town in June, 1807; so that she is now (1856) forty-nine years old. At four years of age she was seized with typhus fever; was taken sick on the evening of Monday, November 29, 1811; and, on the Saturday morning following, became both *blind* and *deaf*. Prior to her illness, she had not only learned to speak, but to repeat her letters, and to spell words of two or three syllables; and, for some time after the loss of her sight and hearing, she was fond of taking a book, and spelling words and the names of her acquaintances. She retained her speech pretty well for about a year; but gradually lost it, and appears to be now condemned to perpetual silence. For three years she could still utter a few words, one of the last of which was "*mother*." At first she was unconscious of her misfortune, appearing to think, that a long night had come upon the world; and often said, "It will never be day." She would call upon the family to "light the lamp," and was impatient at their seeming neglect, in not even answering her. At length, in passing a window, she felt the sun shining warmly upon her hand; and pointed with delight to indicate that she recognized this. From the January after her illness, until the following August, she would sleep during the day, and be awake through the night; and it was not until autumn, by taking great pains to keep her awake during the day, that she was set right. At present, she is as regular in this respect as other persons. From the period of her recovery, she seemed to perceive the return of Sabbath; and, on Sunday morning, would get her own clean clothes, and those of the other children. If her mother was reading, she would find a book, and endeavour to do so likewise. The intervention of a day of fasting or thanksgiving confused her reckoning; and some time elapsed before she got right. During the first winter after her recovery, she was irritable almost to madness; would exhibit the most violent passion, and use the most profane language. The next summer she became calmer; and her mother could govern her, to some extent, by shaking her, in sign of disapprobation; and stroking or patting her head, when she conducted herself well. She is now habitually mild, obedient and affectionate. During the first summer after her illness, she was very unwilling to wear clothes, and would pull them off violently. At length, her mother took one of her frocks and tried it on her sister, with a view of altering it for her. Julia had ever been remarked for her sense of justice in regard to property. This seemed to be awakened; and she took the frock and put it on herself. After this she was willing to wear clothes, and even cried for *new ones*. She has ever since been fond of dress. At nine years of age she was taught to sew; and, since that time, has learned to knit. She has been a resident for several years in the American Asylum at Hartford; where

[1] Twenty-first Report of the Directors of the American Asylum at Hartford, for the Education and Instruction of the Deaf and Dumb, p. 15, Hartford, 1837, et seq.

she is supported in part by the voluntary contributions of visitors, and, in part, by her own labours in sewing and knitting. A language of palpable signs was early established as a means of communication with her friends; and this has been so improved as to be sufficient for all necessary purposes. Her countenance, as she sits at work, exhibts the strongest evidence of an active mind, and a feeling heart; "thoughts and feelings," says a writer who describes her case, "seem to flit across it like the clouds in a summer sky; a shade of pensiveness will be followed by a cloud of anxiety or gloom: a peaceful look will perhaps succeed; and, not unfrequently, a smile lights up her countenance, which seems to make one forget her misfortunes. But no one has yet penetrated the darkness of her prison house, or been able to find an avenue for intellectual or moral light. Her mind seems, thus far, inaccessible to all but her Maker." She was seen by the Author in the summer of 1855; and impressed him as remarkable for the extent of her intellectual sphere under such privations.

A still more interesting example is cited by Dr. Abercrombie[1] from the Medical Journals of the time. A gentleman in France lost every sense except feeling on one side of his face; yet his family acquired a method of holding communication with him, by tracing characters upon the part which retained its sensation. These cases are not, perhaps, so unfrequent as has been supposed. Dr. Howe, the superintendent of the Perkins Institution and Massachusetts Asylum for the Blind, stated, some years ago, that four cases in New England, besides that of Julia Brace, had come within his own observation. One of these had been, in 1841, upwards of three years under his care; and the results of his diligence and judgment in this instance have furnished more gratifying results to the psychologist and philanthropist than any, perhaps, on record.

Laura Bridgman, the subject of the case, was born in December, 1829. At two years of age, her eyes and ears inflamed, suppurated, and their contents were discharged. At the expiration of two more years of suffering, it was discovered, that her sense of smell was almost wholly destroyed; and, consequently, that her taste was much blunted. She had, therefore, but one sense remaining, that of touch, by which she could become acquainted with the external world. Whilst at home, before her reception into the Asylum, she would explore the house; become familiar with the form, density, weight, and temperature of every article she could lay her hands upon; followed her mother; felt her hands and arms, and endeavoured to repeat every thing herself. She even learned to sew a little, and to knit. She exhibited warm affection towards the members of her family; but the means of communicating with her were limited. When it was desired that she should go to a place, she was pushed; or that she should approach, she was drawn towards the person. Gently patting on the head signified approbation; on the back, disapprobation. She had made, however, a natural language of her own; and had a sign to express her idea of each member of the family,—such as drawing her finger down each

[1] Inquiries concerning the Intellectual Powers, &c., Am. edit., p. 56, New York, 1832.

side of her face, to allude to the whiskers of one; twirling her hand and arm around, in imitation of the spinning-wheel, for another, &c.

In October, 1837, she was received into the Institution for the Blind in Boston. The first experiments made with her consisted in taking articles in common use, such as knives, forks, spoons, keys, &c., and pasting labels upon them with their names printed in raised letters. These she felt very carefully; and speedily found, that the crooked lines *spoon* differed as much from the crooked lines *key*, as the spoon differed from the key in form. Small detached labels, with the same words printed upon them, were then put into her hands, and she soon observed, that they were similar to the ones pasted on the articles. She showed her perception of this similarity by laying the label *key* upon the key, and the label *spoon* upon the spoon. In this manner she proceeded to acquire a knowledge of language; used the manual alphabet of the deaf mutes with great facility and rapidity, and increased her vocabulary so as to comprehend the names of all common objects. She could soon count to high numbers; and add and subtract small ones. But the most gratifying acquirement which she made, and the one which gave her the most delight, was the power of *writing a legible hand*, and expressing her thoughts upon paper. She writes with a pencil in a grooved line, and makes her letters clear and distinct. The author has a favourable specimen now before him, in a recent well conceived, and well expressed, letter to a friend. She is expert with her needle; knits easily, and can make twine bags and various fancy articles very prettily; is docile; has a quick sense of propriety; dresses herself with great neatness, and is always correct in her deportment. No definite course of instruction could be marked out; for her inquisitiveness was so great, that she was very much disconcerted if any question, which occurred to her, was deferred until the lesson was over. It was deemed best to gratify her, if her inquiry had any bearing on the lesson; and often she led her teacher far away from the objects with which he commenced. With regard to the sense of touch it is very acute, even for a blind person. It is shown remarkably in the readiness with which she distinguishes persons. There were, a few years ago, forty inmates in the female wing, with all of whom she was acquainted. Whenever she is walking through the passage-way, she perceives by the jar of the floor, or the agitation of the air, that some one is near her, and it is exceedingly difficult to pass her without being recognized. Her arms are stretched out, and the instant she grasps a hand, a sleeve, or even part of the dress, she knows the person, and lets him pass on with some sign of recognition.

The details concerning this interesting being, and her gradual progress in moral and intellectual culture, can be learned from the annual reports of the Institution, which Dr. Howe so ably superintends.[1]

How strongly do these cases demonstrate the independence of the organ of intellect; requiring, indeed, the external senses for its perfect developement, but still capable of manifesting itself without the pre-

[1] Annual Reports of the Trustees of the Perkins Institution and Massachusetts Asylum for the Blind to the Corporation, for the years 1837, et seq. For an account of many interesting cases of the kind, see Dr. Kitto, The Lost Senses. London, 1853.

sence of many, and probably of any, of them; and how inaptly, although humanely, does the law regard such beings! "A person," says Blackstone,[1] "born *deaf*, *dumb*, and *blind*, is looked upon by the law as in the same state with an idiot, he being supposed incapable of any understanding, as wanting all those senses which furnish the human mind with ideas." But if he *grow* deaf, dumb, and blind, not being *born* so, he is deemed *non compos mentis*, and the same rules apply to him as to other persons supposed to be lunatics. With regard to the deaf and dumb, they are properly held to be competent as witnesses, provided they evince sufficient understanding,—and to be liable to punishment for a breach of the criminal laws.

M. Cabanis[2] embraces the views of Condillac regarding the external senses; but thinks, that impressions from these are insufficient to constitute the *matériel* of the mental and moral manifestations. In confirmation of this opinion, he observes, that the young infant, and animals at the very moment of birth, frequently afford evidences of complicated acts originating in the nervous centres; and yet the external senses can have been but little impressed. How can we, he asks, refer to the operation of the external senses the motions of the fœtus in utero, which are perceptible to the mother, for the latter half of utero-gestation; or the act of sucking executed from the first day of existence? Can we refer to this cause the fact of the chick, as soon as it is hatched, pecking the grain that has to nourish it? or the one, so frequently quoted from Galen, of the young kid, scarcely extruded from the maternal womb, and yet able to select a branch of the cytisus from other vegetables presented to it? Man and animals, continues M. Cabanis, during the course of their existence, experience mental changes as remarkable as they are frequent; yet nothing in the condition of the senses can account for such difference. For example, at the period of puberty, a new appetite is added; and this, even, when the being is kept in a complete state of isolation. This, he argues, it is impossible to refer to any change in the external senses; which, if they furnished the materials at all, must have been doing so from early infancy; and he concludes, that the difference observable in the mental manifestations, according to sex, temperament, climate, state of health or disease, regimen, &c., cannot be referable to the senses, as they remain the same; and, consequently, we must look elsewhere for the causes of such difference. These M. Cabanis conceives to be the movements by which the organs of internal life execute their functions. Such movements, he says, although deep-seated and imperceptible, are transmitted to the brain, and furnish that organ with a fresh set of materials. At puberty, when the testicles become developed, and their function is established by the secretion of sperm, the organic movements during the secretion are the materials of the new desires, which appear at that age. These impressions he calls *internal*, in contradistinction to the *external*, or those furnished by the five senses; and he considers, that whilst the external senses serve as the basis for all that we include under the term *intellect*, the internal impressions are the materials of

[1] Commentaries on the Laws of England, i. 304.
[2] Rapport du Physique et du Moral, edit. cit.

what are called *instincts;* and, as the organs of internal life, whence the internal impressions proceed, vary more than the senses, according to age, sex, temperament, climate, regimen, &c., it is more easy to find in them organic modifications, which coincide with those exhibited by the mind under those various circumstances.

In proof of these opinions, he adduces, besides others, the following specious affirmations. *First.* As the venereal appetite appears in man and animals synchronously with the developement of the testicles, and is never exhibited when they are removed in infancy, we have reason to believe, that the impressions, which constitute the materials for this new catenation of ideas, must proceed from the testicles. *Secondly.* Numerous facts demonstrate, that the condition of the uterus has much influence on the mental and moral manifestations of the female. The period of the developement of that organ, for example, is the one at which new feelings arise, and all those manifestations assume more activity; and there is generally a ratio between their activity and that of the uterus. If the state of the uterus be modified, as it is at the menstrual period, or during pregnancy, or after delivery, the mind is so likewise. All these facts ought to induce a belief, he thinks, that impressions are continually emanating from that organ, which, by their variety, occasion the diversity in the state of mental and moral faculties observed in those different cases. *Thirdly.* It is impossible in the *hypochondriac* and *melancholic* constitutions, to mistake the influence exerted upon the mind by the abdominal organs. According as they execute their functions more or less perfectly, the thinking faculty is more or less brilliant or languid; and the affections more or less vivid and benevolent, or the contrary; hence the expressions *melancholy*[1] and *hypochondriasis*,[2] assigned to the states of mind characterizing those constitutions, which denote that the cause must be referred to the abdominal organs. The origin of the alternations of inactivity and energy in the intellect, of benevolent and irascible fits of humour, as well as of insanity, is also referable, he says, to the abdominal viscera. Hence—M. Cabanis concludes—it is evident, that the abdominal organs are the source of fortuitous and abnormous impressions which excite the brain to irregular acts;—and is it not, he asks, probable, that what takes place in excess, in these morbid movements, may happen to a less and more appropriate extent in health; and that thus impressions may emanate in a continuous manner from every organ of the body, which may be indispensable to the production of the mental and moral acts? M. Cabanis, therefore, considers that the axiom of Aristotle should be extended; and that the statue of Condillac is incomplete, in not having internal organs for the emanation of internal impressions, which are the materials of the instincts. In this way he accounts for the instincts, which, by some metaphysicians, have been looked upon as judgments, executed in the ordinary manner, but so rapidly, that the process has ceased from habit to be perceptible. *Finally,* he remarks, there is a ratio between the duration and intensity of the intellectual results and the kind of impressions, which have constituted their materials. All the mental and

[1] From μελας, "black," and χολη, "bile."

[2] Disease of the hypochondres.

moral acts, for instance, that are derived from impressions engendered in the very centre of the nervous system or in the brain,—such as those of the maniac,—are the strongest and most durable. After these come the *instincts*, of which the internal impressions are the materials: they are powerful and constant;—and lastly, the intellectual acts, which are more transient, because they emanate from external impressions, themselves fickle, and somewhat superficial.

According to the views, then, of M. Cabanis and his followers, amongst the organic conditions of the mental and moral manifestations must be placed, not only those of the encephalon and external senses, but of the different organs of the body, which furnish the various internal impressions. The influence of the external senses on the intellectual and moral developement has already been canvassed: we have seen, that they are only secondary instruments for making us acquainted with external bodies, and that they in nowise regulate the intellectual and moral sphere. The notion of internal impressions is ingenious, and has led to important improvements in the mode of investigating the different mental and moral phenomena. It was suggested, as has been shown, by M. Cabanis, in consequence of the external senses appearing to him insufficient to explain all the phenomena. By MM. Gall, Adelon,[1] and others, however, all these cases are considered explicable by the varying condition of the brain itself. In the fœtus in utero; in the new-born animal, there are already parts of the brain, they say, sufficiently developed; and, accordingly, we witness the actions to which reference has been made by M. Cabanis; and if the intellectual and moral manifestations vary according to sex, temperament, climate, regimen, state of health, &c., it is because the encephalon is, under these circumstances, in different conditions. The chief facts, on which M. Cabanis rests his doctrine, are,—the coincidence between the developement of the testicles and the appearance of the venereal appetite; and the suppression of this appetite after castration. It must be recollected, however, that these are not the only changes, that happen simultaneously at puberty. The voice assumes a very different character; but the change in the voice is not a cerebral phenomenon. It is dependent upon the developement of its organ, the larynx. Yet castration, prior to puberty, has a decided effect upon it; preventing it from becoming raucous and unmelodious. All these developements are synchronous; but not directly consequent upon each other. The generative function has two organs,—one *central*, the other *external;* and it is not surprising, that both should undergo their developement at the same period.

On the whole, we are perhaps justified in concluding, that the brain alone is the organ of the intellectual and moral faculties. Yet, as before remarked, there is great force in the facts and arguments brought forward by Dr. Carpenter in favour of the emotional acts being seated in what, he terms, the sensorial ganglia: and that as we descend in the animal scale, the cerebrum or organ of the mental manifestations becomes less and less developed, until we ultimately find an encephalic organization in which a common sensorium for the

[1] Physiologie de l'Homme, 2de édit., i. 251.

reception of sensation and the origination of motion may alone exist; without any organ for the recording of impressions like the cerebrum in more highly endowed organisms. In such case, the motions may be mere responses to sensations experienced, without the presence of the slightest consciousness on the part of the being, or knowledge of the adaptation of means to ends. Still, it may be a question whether such sensations and responsive motions are not possessed by animals devoid of anything resembling the encephalic sensory ganglia of higher organisms, and which are wholly supplied with nerves of the excito-motory class—as the stomato-gastric. The interesting topic of the various instinctive operations of the frame will be considered in another part of this work. We shall there find, that instinct cannot in all cases be defined, in the language of M. Broussais,[1] to consist in sensations originating in the internal and external sensitive surfaces, which solicit the cerebral centre to acts necessary for the exercise of the functions,—such acts being frequently executed without the participation of mind, and even in its absence,—inasmuch as it is not confined to beings possessed of brain, and exists also in the vegetable.

Having now decided upon the organ of the mental and moral faculties, it would be necessary, according to the system adopted in this work, to describe its anatomy; but this has been done elsewhere.

PHYSIOLOGY OF THE INTELLECTUAL AND MORAL FACULTIES.

When the organ of the intellect is exposed by accident, and we regard it during the reception of a sensation, the exercise of volition, or during any intellectual or moral operation, the action is found to be too molecular to admit of detection. At times, during violent mental contention, a redness of the surface of the brain has been apparent, as if the blood had been forced more violently into the vessels; but no light has been thrown by such examination on the wonderful actions that constitute thought. We ought not, however, to be surprised at this, when we reflect, that the most careful examination of a nerve does not convey to us the slightest notion how an impression is received by it from an external body; and how such impression is conveyed to the brain. All that we witness in these cases is the result; and we are, therefore, compelled to study the intellectual and moral acts by themselves, without considering the cerebral movements concerned in their production. Such study is the basis of a particular science—*metaphysics*, *ideology*, or *philosophy*. Apart from organization, this subject does not belong to physiology; but as some of the points of classification, &c., are concerned in questions that will properly fall under consideration, it may be well to give a short sketch of the chief objects of metaphysical inquiry; which are, indeed, intimately connected in many of their bearings,—as commonly treated by the metaphysician,—with physiology. M. Broussais has considered, that metaphysics and physiology should be kept distinct; and that all the investigations of the metaphysician should be confined to the ideal. "I wish metaphysicians, since they so style themselves," he remarks,

[1] Physiol. appliquée à la Pathologie, ch. vii.; or Drs. Bell and La Roche's translation, Philad., 1832.

somewhat splenetically, "would never treat of physiology; that they would only occupy themselves with ideas as ideas, and not as modifications of our organs; that they would never speak either of the brain, the nerves, the temperaments, or of the influence of climates, of localities, or of regimen; that they would never inquire whether there are innate ideas, or whether they come through the medium of the senses; that they would not undertake to follow their developements according to age or state of health; for I am convinced that they cannot reason justly on these points. Such questions belong to physiologists, who can unite a knowledge of the moral nature with that of the structure of the human body." "It is possible," he adds, "that particular circumstances may oblige them to introduce physiological considerations into their calculations; as when it is necessary to estimate the influence of certain laws or customs in relation to temperature, the nature of the soil, the prevailing diseases, &c., but then they should avail themselves of the experience of physiologists and physicians."[1] A more appropriate recommendation would be that the metaphysician should make a point of becoming acquainted with physiological facts and reasoning; and, conversely, that metaphysics should form a part of the study of every physiologist.

The cerebral manifestations comprise two very different kinds of acts;—the *intellectual* and the *moral;* the former being the source of all the knowledge we possess regarding ourselves and the bodies surrounding us; the latter comprising our internal feelings, appetites, desires, and affections, by which we are incited to establish a relation with the beings around us:—the two sets of acts respectively embracing the *qualities of the mind*, and those *of the heart*.[2]

If we attend to the different modes in which the intellectual manifestations are evinced in our own persons, we find, that there are several acts which are by no means identical. We are conscious of the difference between appreciating an impression made upon one of the external senses, which constitutes *perception*, and the recalling of such impression to the mind, which is the act of *memory;* as well as the distinction between feeling the relations that connect one thing with another, constituting *judgment;* and the tendency to act in any direction, which we call *will*. The consciousness of these various mental processes has induced philosophers to admit the plurality of the intellectual acts, and to endeavour to reduce them all to certain *primary* faculties; in other words, to faculties which are fundamental or elementary, and by their combination give rise to other and more complex manifestations. To this analytical method they have been led by the fact, that the different acts, which they esteem elementary, exhibit great variety in their degrees of activity: one, for example, may be impressed with a character of energy—as the memory;—whilst another, as the judgment, may be singularly feeble;—and conversely. M. Broussais conceives, that without the memory we cannot exercise a single act of judgment; as it is always necessary, in order to judge, that we should experience

[1] De l'Irritation et de la Folie, Paris, 1828; or Dr. Cooper's translation, Columbia, S. C., 1831.

[2] Adelon, Facultés de l'Esprit et de l'Ame, in Dict. de Méd., viii. 469, Paris, 1823; and Physiologie de l'Homme, edit. cit., i. 527.

two successive perceptions, which we could not do, unless possessed of the faculty of renewing that which we had felt before; in other words, unless we possessed memory. Hence the loss of this faculty, he says, necessarily occasions that of judgment, and reduces man to a state of imbecility. To a certain extent this is true. Total privation of memory must be attended with the results described. If an individual retains no consciousness of that which impressed him previously, there can obviously be no comparison. A man may, however, have an unusual memory for certain things and not for others; he may astonish us by the extreme accuracy of his recollection of numbers, places, or persons; and yet he may be singularly deficient in judging of other matters;—his memory suggesting only one train of objects for comparison.

In enumerating the faculties, which, by their union, constitute the intellect, we observe great discrepancy amongst metaphysicians. Some admit *will*, *imagination*, *understanding*, and *sensibility;* others, *sensibility*, *imagination*, *memory*, and *reason;* others *will*, *intelligence*, and *memory;* and others, again, *imagination*, *reflection*, and *memory*. The views of M. Condillac[1] on this subject have perhaps excited more attention than those of any other individual. Professing, as we have seen, that all our ideas are derived from successive operations of the senses and the mind, he admits the following constituent faculties of the intellect:—*sensation*, *attention*, *comparison*, *judgment*, *reflection*, *imagination*, and *reason*. *Sensation* he defines to be—the faculty of the mind, which affords the perception of any sensitive impression. *Attention*, the faculty of sensation, applied exclusively to a determinate object; being, as the word imports, the tension of the mind upon a particular object. *Comparison*, the faculty of sensation, applied to two objects at once. *Judgment*, the faculty by which the mind perceives the connexions, that exist between the objects compared. *Reason*, the faculty of running through a succession of judgments, which are connected with, and deduced from, each other. *Reflection*, as the word indicates, the faculty by which the mind returns upon itself, upon its own products, to prove their correctness, and to subject them again to its power; and *imagination*, to which Condillac attaches *memory*,—the faculty possessed by the mind of reproducing at will the different impressions, and all the products of its own operations. With regard to the order of catenation of these different faculties, he considers *sensation* to be first put in play; and if, amongst the perceptions, there is one, of which we have a more lively consciousness, and which attracts the mind to it alone, it is the product of *attention:* then comes *comparison*, which is nothing more than double attention: comparison is irresistibly succeeded by *judgment:* if, from one judgment, we pass to another deduced from it, we *reason:* if the mind turns back on its own production, we *reflect:* and lastly, if the mind spontaneously awakens its different perceptions *imagination* is in action. All these faculties are thus made to be deduced from each other; to originate in the first or sensation; and all are sensation successively transformed.

The doctrine of M. Condillac, abstractly considered, has already engaged attention. The division of the faculties, which he conceives, by

[1] Op. citat.

their aggregation, to form the intellect, is simple and ingenious, and appears to be more easily referable to physiological principles than that of other metaphysicians; accordingly, it has been embraced, with more or less modification, by certain physiological writers.

The power of reflection, according to M. Broussais, is the characteristic of the human intellect; and to reflect is to feel. Man not only feels the stimulation produced by external agents, and by the movements of his own organs, which constitutes *sensation* or *perception*, but he is conscious that he has felt these stimulations: in other words, he *feels that he has felt;* he has, consequently, a perception of his actual perception, which, M. Broussais says, constitutes mental *reflection*. This process he can repeat as often as he thinks fit, and can observe all his sensations, and the different modes in which he felt, whilst occupied with his feelings. From this study he derives an idea of his own existence. "He distinguishes himself," to quote the dry description of M. Broussais, "in the midst of creation, and paying regard only to his own existence, compared with all that is not himself, he pronounces the word *I* (*moi*), and says, *I am;* and viewing himself in action, says, *I act*, *I do*, &c. Perception of himself and of other bodies procures him what are denominated *ideas*. This is, therefore, another result of reflection; in other words, of the faculty he possesses of feeling himself feel. But man feels, besides, that he has already felt: this constitutes *memory*. In comparing two perceptions with each other, which are felt in succession, a third perception results, which is *judgment*. Consequently, to judge is only to feel." "Hence," he concludes, "*sensation*, *reflection*, and *judgment* are absolutely synonymous, and present to the physiologist nothing more than the same phenomenon. The *will* or the faculty by virtue of which man manifests his liberty by choosing, among different perceptions, the one he must obey;—the faculty, which gives him the power of resisting, to a certain extent, the suggestions of instinct—is founded on reflection. Consequently, when we consider it in a physiological point of view, we can only discover in it the faculty of feeling ourselves, and of perceiving that we feel ourselves."

Some of the later French metaphysicians have proposed certain modifications of the system of Condillac. M. De La Romiguière,[1] for instance, denies that sensation is the original faculty, and derives all from attention. The mind, he remarks, is passive during the reception of sensation, and does not commence action until directed to some object, or until it *attends*. According to him, the intellect consists of three faculties—*attention; comparison* or double attention; and *reason* or double comparison. Judgment, imagination, and memory are not primary faculties: judgment is the irresistible product of comparison; memory is but the trace, which every perception necessarily leaves behind it; and imagination is but a dependence on reason. M. Destutt-Tracy,[2] again, reduces the number of primary faculties to four—*perception*, *memory*, *judgment*, and *will* or *desire*. According to him, *attention* is not an elementary faculty. It is but the active exercise of the intellectual faculties. The same applies to *reflection* and *reason*, which are only a judiciously combined employment of those faculties; and

[1] Leçons de Philosophie, tom. i. 4ème leçon.
[2] Élémens d'Idéologie, 2de édit., Paris, 1804.

to *comparison* and *imagination*, both of which enter into the judgment. This division is embraced by M. Magendie.[1] Mr. Dugald Stewart's[2] classification is into, 1, *Intellectual powers*, and, 2, *Active* and *moral powers;* including, in the former, *perception*, *attention*, *conception*, *abstraction*, the *associating principle*, *memory*, *imagination*, and *reason*. Dr. Brown[3] reduces all the *intellectual states* to *simple suggestion* and *relative suggestion*,—comprising, in the former, *conception*, *memory*, and *imagination*, —in the latter, *judgment*, *reason*, *abstraction*, and *taste*. Dr. Abercrombie[4] considers the mental operations to be chiefly referable to *four heads*,—*memory*, *abstraction*, *imagination*, and *reason* or *judgment;* whilst Kant has twenty-five primary faculties or forms; pure conceptions or ideas *à priori*.

These are a few only of the discrepant divisions of psychologists. The list might have been extended by the classifications of Aristotle, Bacon, Hobbes, Locke, Bonnet, Hume, Vauvenargues, Diderot, Reid, and others. Perhaps the most prevalent opinion at present is, that the original faculties are—*perception*, *memory*, *judgment*, and *imagination*. It is impossible, were it even our province, to reconcile these discrepancies. They are too considerable to hope, that this will ever be effected by metaphysical inquiry. We must, therefore, look to physiological investigation, if not with well-founded—with the only—hopes, we can entertain, for the elucidation of the subject; and we shall find presently, that the minds of metaphysical physiologists have been turned in this direction, and that many interesting facts and speculations have been the result.

A second topic of metaphysical inquiry regards the formation of the intellectual notions. On this, there have been two principal opinions; some, as Plato, Des Cartes, the Kantists, Kanto-Platonists, &c., believing in the existence of *innate ideas;*—others, as Bacon, Locke, and Condillac, denying—as we have seen—the existence of such innate ideas, and asserting that the human intellect, at birth, is a *tabula rasa;* and that the mind has to acquire and form all the ideas it possesses from impressions made on the senses. The truth includes probably both these propositions,—the action of the senses and intellectual faculties being alike necessary;—the former receiving the external and internal impressions, and transmitting them to the mind, which, through the cerebral organ, produces the latter.

Under the terms *affective faculties*, *affections*, and *passions*, are comprehended all those active and moral powers, which connect us with the beings that surround us, and are the incentives to our social and moral conduct. To this class belong,—the feeling, which attaches the parent to the child; that which attracts the sexes; and compassion, by which we are led to assist a suffering fellow-creature. They are, in truth, internal sensations, but of a higher cast than those of hunger and thirst;—the latter being purely physical, and announcing physical necessities; the former suggesting social and moral relations. Such affective faculties are the foundation of what are called moral wants; and, like the

[1] Précis Élémentaire, i. 196.

[2] Elements of the Philosophy of the Human Mind, 3d edit., Lond., 1808; and Amer. edit., Brattleborough, Vt., 1813.

[3] Lectures on the Philosophy of the Human Mind, Amer. edit., Boston, 1826.

[4] Inquiries concerning the Intellectual Powers, Amer. edit., p. 91, New York, 1832.

internal sensations in general, are the source of *pleasure*, when satisfied,—of *pain*, when resisted; and it is only when they are extreme and opposed, that they acquire the name of *passions*.[1] The analysis of these is attended with the same difficulties as that of the intellectual faculties. Their plurality is universally admitted, but still greater discrepancy exists as to their precise number and connexion.[2] Many moralists have united the moral faculties under the head of *will* or *desires*. Condillac[3] is one of those. Every sensation, he observes, has the character of pleasure or pain, none being indifferent; as soon, therefore, as a sensation is experienced, the mind is excited to act. This tendency is at first but slightly marked, and is only an uneasiness (*malaise*); but it soon increases and becomes *restlessness* or *inquietude*;—in other words, a difficulty experienced by the mind of remaining in the same situation. This gradually becomes *desire*, *torment*, *passion*, and finally *will* excited to the execution of some act. Some have endeavoured, by ultimate analysis, to derive all the affective faculties from one principal faculty—that of *self-love*,—the inward feeling which induces all to attend to themselves, their own preservation, and welfare. All the faculties, they assert, are returns of this self-love upon itself; and, as in the case of the intellectual faculties, attempts have been made to classify them; but scarcely two metaphysicians agree. Some have divided them into the *agreeable* and *distressing*; others into those of *love* and *hatred*; many—regarding their effects upon society—into the *virtuous*, *vicious*, and *mixed*;—the first comprising those that are useful to society,—as *filial*, *parental*, and *conjugal love*, which form the foundation of families; *goodness*, *pity*, and *generosity*, which, by inducing men to assist each other, facilitate the social condition; and the *love of labour*, *honour*, and *justice*, which have the same result, by constituting so many social guarantees. The vicious passions, on the contrary, are such as injure man individually, and society in general, as *pride*, *anger*, *hatred*, and *malice*. Lastly, the mixed passions are such as are useful or injurious, according to their use or abuse; as *ambition*, which may be a laudable emulation, or an insatiable passion, according to its extent and direction.

Again, the passions have been divided into the *animal* or such as belong to physical man, and the *social* or such as appertain to man in society. The first are guides for his preservation as well as for that of the species. To them belong *fear*, *anger*, *sadness*, *hatred*, *excessive hunger*, the *venereal desire* when vehement, *jealousy*, &c. In the second are included all the social wants when inordinately experienced. These vary according to the state of civilization of the individual and the community. *Ambition*, for instance, it is said, may be regarded, when inordinate, as excessive love of power:—*avarice*, as an exaggeration of the desire for fortune:—*hatred*, and *vengeance*, as the natural and impetuous desire of injuring those that injure us, &c. Mr. Dugald Stewart's[4] division of the *active* and *moral powers* embraces, 1. *Instinctive principles*, and 2. *Rational principles*,—the former including *appetites*, *desires*, and *affections*; the latter *self-love* and the *moral faculty*; all of

[1] From *patior*, I suffer.

[2] Adelon, art. Affection, Dictionnaire de Médecine, 1ère édit.; and Physiologie de l'Homme, edit. cit., i. 537.

[3] Op. citat.

[4] Op. citat.

which Dr. Brown[1] comprises under *emotions*, immediate, retrospective, or prospective;—and *lastly*, Dr. Abercrombie[2] refers all the principles, which constitute the moral feelings, to the following heads: 1. The *desires*, the *affections*, and *self-love;* 2. The *will;* 3. The *moral principle*, and 4. The *moral relation of man towards the Deity*.

It is obvious, that the analysis of the moral faculties has been still less satisfactorily executed than that of the intellectual; and that little or no attempt has been made to distinguish those that are primary or fundamental from those that are more complex; consequently, the remarks which were made regarding the only quarter we have to look to, for any improvement in our knowledge of the intellectual acts, apply *à fortiori* to the moral; although it must be admitted, that the difficulties attendant upon the investigation of the latter are so great as to appear to be almost insuperable.

As the brain, then, is admitted to be the organ of the intellectual and moral faculties, it is fair to presume that its structure may be found to vary according to the number and character of those; and if there be primary or fundamental faculties, each may be conceived to have a special organ concerned in its production, as each of the external senses has its organ. According to this view, the cerebral organization of animals ought to differ according to their psychology: where one is simple, the other should be so likewise. This seems, so far as we can observe, to be essentially the fact. "In the series of animals," says M. Adelon,[3] "we observe the brain more complicated as the mental sphere is more extensive; and in this double respect a scale of gradation may be formed from the lowest animals to man. If he has the most extensive moral sphere, if he alone has elevated notions of religion and morality, he also has the largest brain, and one composed of more parts; so that if the physiology of the brain were more advanced, we might be able, by comparing the brains of animals with his, to detect the material condition, which constitutes humanity. If the brain were not constructed *à priori* for a certain psychology, as the digestive apparatus is for a certain alimentation; and if the mental and moral faculties were not as much innate as the other faculties, there would be nothing absolute in legislation or morals. The brain and its faculties are, however, in each animal species, in a ratio with the *rôle*, which such species is called upon to play in the universe. If man is, in this respect, in the first rank; if he converts into the delicate affections of father, son, husband, and country, those brute instincts by which the animal is attached to its young, its female, or kennel; if, in short, he possesses faculties which animals do not,—religious and moral feelings, with all those that constitute humanity,—it is owing to his having a more elevated vocation; to his being not only king of the universe, but destined for a future existence, and specially intended to live in society. Hence it was necessary, that he should not only have an intellect sufficiently extensive to make all nature more or less subject to him, but also a psychology such, that he might establish social relations with his fel-

[1] Op. citat.

[2] Philosophy of the Moral Feelings, Amer. edit., p. 35, New York, 1833.

[3] Art. Encéphale, in Dict. de Méd., vii. 526; and Physiologie de l'Homme, edit. cit., i. 524.

lows. It was necessary, that he should have notions of the just and the unjust, and be able to elevate himself to the knowledge of God;—to those sublime feelings, which cause him so to regulate his conduct as to maintain with facility his mortal connexions, and deserve the future life to which he is called."

But if the intellectual sphere be regulated by the cerebral developement, can we not, it has been asked, estimate the connexion between them? And if there be different primary cerebral faculties, each of which must have an organ concerned in its production, can we not point out such organ in the brain? Several investigations of this character have been attempted, with more or less success: generally, however, they have added but little to our positive knowledge, and this, principally, from the intricacy of the subject. Until of late years, attention was chiefly paid to the mass and size of the encephalon; and it was, at one time, asserted that the larger it is, in any species or individual, the greater the intellect. Man, however, has not absolutely the largest encephalon, although he is unquestionably the most intelligent of beings. The weight of the encephalon of a child six years of age is given by Haller at two pounds three ounces and a half; whilst that of the adult is estimated by Sömmering at from two pounds three ounces, to three pounds three ounces and three-quarters;[1] by Tiedemann[2] at from three pounds three ounces, to four pounds eleven ounces troy,—the brain of the female weighing, on an average, from four to eight ounces less than that of the male. The average weight, after the meninges have been stripped off, is, in the healthy adult male, according to M. Lelut,[3] about 1346 grammes or three pounds and a half avoirdupois; of which the cerebrum weighs 1170, the cerebellum 176 grammes. In the female, the weight of the encephalon was about $\frac{1}{13}$th less. From the tables of weights of the brain given by Dr. Sims, Clendinning,[4] Tiedemann, and Dr. John Reid,[5] it was found that in a series of 278 cases the maximum weight of the adult male brain was 65 ounces: the minimum weight 34 oz. In a series of 191 cases, the maximum weight of the brain of the adult female was 56 oz.:—the minimum weight 31 oz. By taking the mean of all the cases, an average weight was deduced of 49½ oz. for the male; and of 44 oz. for the female brain; and although many female brains exceed in weight particular male brains, it is found that the adult male encephalon is heavier than that of the female, by from five to six ounces on an average.[6] The encephalon of the elephant, according to Haller, weighs from seven to ten pounds. The brain of an African elephant, seventeen years old, was found by Perrault to weigh nine pounds; that of an Asiatic elephant, weighed by A. Moulins, was ten pounds. Sir Astley

[1] Weber's Hildebrandt's Handbuch der Anatomie, Band iii. 423; Rudolphi, Grundriss, u. s. w. ii. 11, Berlin, 1823.

[2] Proceedings of the Royal Society for 1836; also Das Hirn des Negers mit des Europäers und Orang-outangs vergleichen, Heidelb., 1837, cited in Brit. and For. Med. Rev., for Oct., 1839, p. 374.

[3] Gazette Médicale; and Medico-Chirurgical Review for Oct., 1837, p. 507.

[4] Medico-Chirurgical Transactions, xix. 353.

[5] Lond. and Edinb. Monthly Journal of Medical Science, April, 1843, p. 298.

[6] Quain's Human Anatomy, by Quain and Sharpey, Amer. edit. by Leidy, ii. 185, Philad., 1849.

Cooper dissected one that weighed eight pounds one ounce and two grains, avoirdupois.[1]

These facts, consequently, overthrow the proposition; and, moreover, in certain insects, the bee and the ant, we meet with evidences of singular intelligence. The proposition was therefore modified, and it was laid down, that the larger the encephalon, compared with the rest of the body, the greater the mental sphere. When the subject was first investigated in this way, the result, in the case of the more common and domestic animals, was considered so satisfactory, that without farther comparison the proposition was considered established. More modern researches have shown, that it admits of numerous exceptions; and that several of the mammalia, and many diminutive and insignificant animals have the advantage over man in this respect. It has, indeed, been properly observed by Mr. Lawrence,[2] that it cannot be a very satisfactory mode of proceeding, to compare the body, of which the weight varies so considerably, according to illness, emaciation, or *embonpoint*, with the brain, which is affected by none of those circumstances, and appears to remain constantly the same. This is the cause why, in the cat, the weight of the encephalon compared with that of the body has been stated as 1 to 156 by one comparative anatomist; and as 1 to 82 by another; that of the dog as 1 to 305 by one, and as 1 to 47 by another, &c.

The following table, taken chiefly from Haller[3] and Cuvier,[4] exhibits the proportion borne by the encephalon to the rest of the body in man and certain animals.

Child, 6 years old	$\frac{1}{22}$	Elephant	$\frac{1}{500}$
Adult	$\frac{1}{35}$	Stag	$\frac{1}{290}$
Gibbon	$\frac{1}{48}$	Roebuck (young)	$\frac{1}{194}$
Sapajous, from	$\frac{1}{41}$ to $\frac{1}{22}$	Sheep	$\frac{1}{351}$ to $\frac{1}{192}$
Apes	$\frac{1}{48}$ to $\frac{1}{24}$	Ox	$\frac{1}{750}$ to $\frac{1}{860}$
Baboons	$\frac{1}{104}$ to $\frac{1}{86}$	Calf	$\frac{1}{219}$
Lemurs	$\frac{1}{84}$ to $\frac{1}{61}$	Horse	$\frac{1}{700}$ to $\frac{1}{400}$
Bat (vespertilio)	$\frac{1}{96}$	Ass	$\frac{1}{254}$
Mole	$\frac{1}{36}$	Dolphin	$\frac{1}{25}$, $\frac{1}{36}$, $\frac{1}{66}$, $\frac{1}{102}$
Bear	$\frac{1}{265}$	Eagle	$\frac{1}{260}$
Hedgehog	$\frac{1}{168}$	Goose	$\frac{1}{360}$
Fox	$\frac{1}{205}$	Cock	$\frac{1}{25}$
Wolf	$\frac{1}{230}$	Canary Bird	$\frac{1}{14}$
Beaver	$\frac{1}{290}$	Humming Bird[5]	$\frac{1}{11}$
Hare	$\frac{1}{228}$	Turtle	$\frac{1}{5688}$
Rabbit	$\frac{1}{140}$ to $\frac{1}{152}$	Tortoise	$\frac{1}{2240}$
Rat	$\frac{1}{76}$	Frog	$\frac{1}{172}$
Mouse	$\frac{1}{43}$	Shark	$\frac{1}{2496}$
Wild Boar	$\frac{1}{672}$	Pike	$\frac{1}{1305}$
Domestic do.	$\frac{1}{512}$ to $\frac{1}{412}$	Carp	$\frac{1}{560}$

In 9 males, between 27 and 50 years of age, who died immediately, or within a few hours after accidents, and other external causes of death, and who had been previously in good health, Dr. John Reid[6] obtained the following results;—the weight used being avoirdupois:—

[1] Dr. Todd, art. Nervous Centres, in Cyclop. of Anat. and Physiol., Pt. xxv. p. 664, Lond., 1844.

[2] Lectures on Physiology, Zoology, &c., p. 191, Lond., 1819.

[3] Element. Physiol., x. sect. 1.

[4] Leçons d'Anat. Comp., ix. art. 5.

[5] On the authority of ex-President Madison.

[6] Lond. and Edinb. Monthly Journal of Med. Science, April, 1843, p. 322.

Average weight of body (9 weighed)	134 lbs. $3\frac{1}{2}$ oz.
Average of encephalon (6 weighed)	3 lbs. 4 oz. $4\frac{4}{6}$ dr.
Average of cerebellum (4 weighed)	5 oz. $7\frac{1}{5}$ dr.
Average of cerebellum with pons and medulla (5 weighed)	6 oz. 6 dr.
Or, taking the average of the four cases only in which the cerebellum was taken	6 oz. $7\frac{7}{8}$ dr.
Average of heart (9 weighed)	12 oz. 6 dr.
Relative weight of body to encephalon (6 weighed) . . .	as 1 to $40\frac{4}{5}$
Relative weight of body to heart (9 weighed)	as 1 to $173\frac{1}{3}$
Relative weight of encephalon to cerebellum (4 weighed) . .	as 1 to $9\frac{2}{5}$
Relative weight of encephalon to cerebellum, with pons and medulla (5 weighed)	as 1 to $8\frac{6}{19}$

M. Bourgery[1] found, that the mean weight of the encephalon being 20393·5 grains troy, the cerebral hemispheres weigh 16940·46 grains; the cerebellum, 2176·7 grains; the cephalic prolongation of the cerebro-spinal axis, 1312·2 grains; of which the optic thalami and corpora striata make 879·9 grains; the medulla oblongata with the pons Varolii 432·2 grains; and the spinal cord 710·1 grains. Hence, in man, the cerebral hemispheres include a nervous mass, which is four times greater than the rest of the cerebro-spinal mass; nine times greater than the cerebellum; thirteen times greater than the cephalic stem of the spinal cord; and twenty-four times greater than the spinal cord itself.

It has been the general belief, that the brain of the negro is inferior to that of the white variety of the species; but certain observations of M. Tiedemann led him to the belief, that there is no perceptible difference either in its average weight or average size in the two varieties, and that the nerves compared with the size of the brain are not larger in the former than in the latter. In the external form of the brain of the negro a very slight difference only could be traced; and he affirmed further, that there is absolutely no difference in its external structure, nor does the negro brain exhibit any greater resemblance to that of the ourang outang than the brain of the European, excepting, perhaps, in the more symmetrical disposition of its convolutions. Tiedemann's observations were made, however, upon few subjects; and his own facts do not bear out all his deductions. He admits, that the anterior part of the hemispheres was something narrower than is usually the case in Europeans, "which,"—says Dr. Combe,[2]—"as the anterior portion is the seat of intellect, is really equivalent to conceding that the negro is naturally inferior in intellectual capacity to the European." M. Tiedemann established that the average capacity of the Ethiopian skull is somewhat less than that of the European, and that a large sized skull is considerably less frequent among them than among any other races of mankind.[3]

The following table, drawn up by Dr. Morton,[4] exhibits the absolute capacity of the cranium or bulk of the encephalon in cubic inches, obtained by filling the cavity of the crania with leaden shot, one-eighth of an inch in diameter, in different races and families of man.[5] It sufficiently exhibits how little can be judged, in this manner, of their relative intellectual aptitudes.

[1] Lond. Med. Gaz., Jan., 1845, p. 462. [2] Phrenological Journal, No. liv., Dec., 1837.

[3] Brit. and For. Med. Rev., for Oct., 1839, p. 379.

[4] Catalogue of Skulls of Man and the Inferior Animals in the collection of Samuel George Morton, M. D., &c., 3d edit., p. viii., Philad., 1849.

[5] For the ingenious process invented by Mr. J. S. Phillips, of Philadelphia, by which these measurements were taken, see Dr. Morton's Crania Americana, p. 253, Philad. and Lond., 1839.

TABLE,

Showing the Size of the Encephalon in cubic inches, as obtained from the measurements of 623 Crania of various Races and Families of Man.

(N. B.—I. C. means Internal Capacity.)

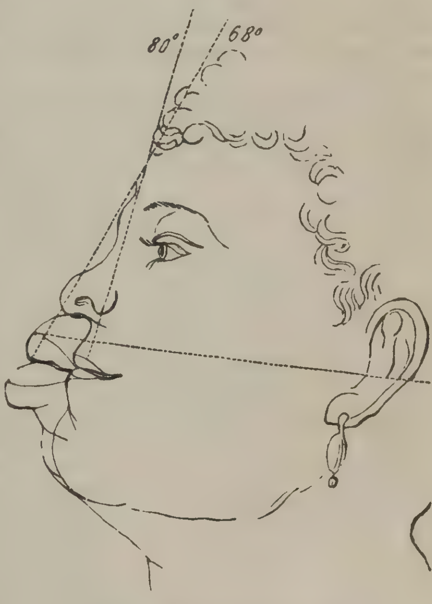
RACES AND FAMILIES.	No. of Skulls.	Largest. I. C.	Smallest. I. C.	Mean.	Mean.
MODERN CAUCASIAN GROUP.					
TEUTONIC FAMILY.					
Germans,	18	114	70	90	92
English,	5	105	91	96	
Anglo-Americans,	7	97	82	90	
PELASGIC FAMILY. *Persians, Armenians, Circassians,*	10	94	75	84	
CELTIC FAMILY. *Native Irish,*	6	97	78	87	
INDOSTANIC FAMILY. *Bengalees, &c.,*	32	91	67	80	
SEMITIC FAMILY. *Arabs,*	3	98	84	89	
NILOTIC FAMILY. *Fellahs,*	17	96	66	80	
ANCIENT CAUCASIAN GROUP.					
From the Catacombs. PELASGIC FAMILY. *Græco-Egyptians,*	18	97	74	88	
From the Catacombs. NILOTIC FAMILY. *Egyptians,*	55	96	68	80	
MONGOLIAN GROUP.					
CHINESE FAMILY,	6	91	70	82	
MALAY GROUP.					
MALAYAN FAMILY,	20	97	68	86	85
POLYNESIAN FAMILY,	3	84	82	83	
AMERICAN GROUP.					
TOLTECAN FAMILY.					
Peruvians,	155	101	58	75	79
Mexicans,	22	92	67	79	
BARBAROUS TRIBES. *Iroquois, Lenapé, Cherokee, Shoshoné, &c.,*	161	104	70	84	
NEGRO GROUP.					
NATIVE AFRICAN FAMILY,	62	99	65	83	83
AMERICAN-BORN NEGROES,	12	89	73	82	
HOTTENTOT FAMILY,	3	83	68	75	
ALFORIAN FAMILY, *Australians,*	8	83	63	75	

From this table it appears, that the smallest mean cranial capacity is found in the Hottentots and Australians, which is 75 cubic inches; whilst that of the Teutonic races is 92 cubic inches. It may be interesting to add, that from the examination of four skulls of the Engé-ena, a quadrumanous animal—Troglodytes *gorilla*, of Savage—from Gaboon in Africa, Dr. Jeffries Wyman[1] found the mean capacity, measured according to the method employed by Dr. Morton, to be $28{\cdot}9\frac{1}{2}$ cubic inches, or considerably less than one-half the mean of the Hottentots and Australians, who afford the minimum average for the human family. The mean cranial capacity of three adult chimpanzees was even less, or 24 cubic inches.

Wrisberg and Sömmering[2] proposed another point of comparison—the ratio of the mass of the encephalon to that of the rest of the nervous system; and they asserted, that in proportion as any animal possesses a larger share of the former; or, in other words, in proportion as the percipient and intellectual organ exceeds the other or the organ of the external senses, the mental sphere may be expected to be more diversified and developed. But although man is, in general, pre-eminent in this respect, he is not absolutely so. It would be still more important to know the ratio, which the cerebrum or brain proper bears to the cerebellum and medulla oblongata. The first is essentially the organ of intellect; and the most striking character of the human brain is the large developement of the cerebral hemispheres, of which we have no parallel in the animal kingdom. The last is the encephalic part in which the nerves of sense arise or terminate.

The assertion, that man has the largest cerebrum in proportion to the cerebellum, is not accurate. The Wenzels[3] found the ratio, in him, to be as $6\frac{51}{129}$ or $8\frac{42}{121}$ to 1; in the horse, $4\frac{1}{2}$ to 1; in the cow, $5\frac{173}{211}$ to 1; in the dog, $6\frac{4}{29}$ to 1; in the cat, $4\frac{4}{15}$ to 1; in the mole, $3\frac{2}{3}$ to 1; and in the mouse, $6\frac{2}{3}$ to 1. Nor is it true that man has the largest cerebrum in proportion

Fig. 319.



Facial Line and Angle of Man.

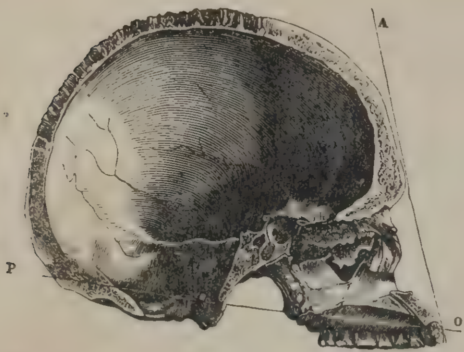
[1] A description of two additional Crania of the Engé-ena, &c., read before the Boston Society of Natural History, Oct. 3, 1849; and published in the American Journal of Science and Arts, second series, vol. ix.

[2] Corpor. Human. Fabric., iv. § 92; and Blumenbach's Comp. Anat. by Lawrence, p. 292, Lond., 1807.

[3] De Penitiori Structur. Cerebr. Hominis et Brutorum, tab. iv.

to the medulla oblongata and medulla spinalis; although to this position there are perhaps fewer objections than to the others. None of them, it is obvious, are distinctive between man and animals, or assist us in solving the great problem of the source and seat of the numerous psychical differences we observe.

Fig. 320.

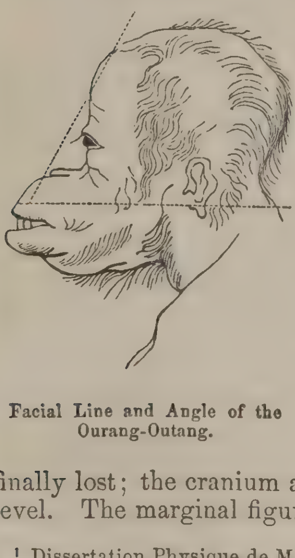


Vertical section of Skull of Papuan Negrito.

Various plans have been devised for appreciating the comparative size of the cranium,—which is generally in a ratio with that of the brain,—and of the bones of the face. As the former contains the organ of the intellect, and the latter those of the external senses and of mastication, it has been presumed, that the excess of the former would indicate the predominance of thought over the senses; and, conversely, that the greater developement of the face would place the animal lower in the scale.

One of these methods, first proposed by Camper,[1] is by taking the course of the *facial line*, and the amount of the *facial angle*. The *facial line* is a line drawn from the projecting part of the forehead to the alveoli of the incisor teeth of the upper jaw; the *facial angle* is that formed between this line and another drawn horizontally backwards from the upper jaw. The course of the horizontal line and its point of union with the facial line are not uniform in all the figures given by Camper: sometimes, it is made to pass through the meatus auditorius externus; but it often falls far below it; yet Dr. Bostock thinks[2] "we cannot hesitate to admit the correctness of Camper s observations, and we can scarcely refuse our assent to the conclusion that he deduces from them." In man, whose face is situate perpendicularly under the cranium, the facial angle is very large. In animals, the face is placed in front of the cranium; and as we descend from man the angle becomes less and less, until it is finally lost; the cranium and face being in most reptiles and fish on a level. The marginal figure (Fig. 319) exhibits the difference between

Fig. 321.



Facial Line and Angle of the Ourang-Outang.

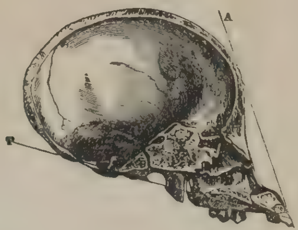
[1] Dissertation Physique de M. Camper, sur les Differences Réelles que presentent les Traits du Visage, &c., traduit du Hollandois, par D. B. Q. Disjonval, Autrecht, 1791.
[2] Physiology, 3d edit., p. 804, Lond., 1836.

the facial angle of one of European descent, and that of the negro. By covering with the finger the parts below the nose alternately, we have the countenance of the white, and negro, in which the facial angle differs as much as 10°, or 15°. Figs. 321, 2, 3, exhibit the facial line

Fig. 322.

Vertical section of Skull of Adult Ourang.

Fig. 323.



Vertical section of Skull of Young Ourang.

and angle of the ourang-outang. Animals that have the snout long, and the facial angle consequently small, have been proverbially esteemed foolish:[1]—such are the snipe, stork, crane, &c.; whilst superior intelligence has been ascribed to those in which the angle is more largely developed,—as the elephant and the owl; although in them, the large facial angle is caused by the size of the frontal sinuses, or by the wide separation between the two tables of the skull, and is necessarily no index of the size of the brain. Yet, from this cause, perhaps, the owl was chosen as an emblem of the goddess of wisdom; and the elephant has received a name in the Malay language, indicating an opinion, that he is possessed of reason. The following table exhibits the facial angle in man and certain animals, taken by a line drawn parallel to the floor of the nostrils, and meeting another, drawn from the greatest prominence of the alveoli of the upper jaw to the prominence of the forehead:—

Man	68° to 88° or more	Polecat	31°
Sapajou	65°	Pug dog	35°
Ourang-outang	56° or 58°	Mastiff	41°
Guenon	57°	Hare	30°
Mandril	30° to 42°	Ram	30°
Coati	28°	Horse	23°

The facial angle may, then, exhibit the difference between man and animals; and, to a certain extent, between the species or individuals of the latter; but, farther, it is of little or no use.[2] In man, it may be considered to vary from 70° to 85° in the adult; but in children it

[1] Lawrence, op. citat., p. 168.

[2] Dr. Morton, in his splendid work, Crania Americana, Philad., 1839, describes a "Facial Goniometer," originally suggested by Dr. Turnpenny, of Philadelphia, which is admirably adapted for measuring the facial angle.

reaches as high as 90° and upwards; a sufficient proof, that it cannot be regarded as a measure of the intellect. In the European, it has been estimated, on the average, at perhaps, 80°, in the Mongol, 75°, and in the negro, 70°, not many degrees above the Sapajou.[1]

The following table, drawn up from the average of actual measurements of the skulls of different races and families of man, in the collection of Dr. Morton,[2] will afford more precise information on this matter.

	FACIAL ANGLE.		
	Average.	Highest.	Lowest.
Arab (2 cases)	82	88	76
European and Anglo-American	80	85	77
Egyptian	79·3	86	73
Bengalee	79·3	83	76
Circassian	78·5	81	75
Sandwich Islander (one case)	78		
Chinese (one case)	78		
Guanche (one case)	77		
Negro	76·8	83	69
Indian	76·1	84	70
Hottentot (one case)	75		
Peruvian	74·9	81	68
Malay	74.6	82	69

It is found, that the skulls of different nations, and of individuals of the same nation, may agree in the facial angle, whilst there may be striking distinctions in the shape of the cranium and face, in the air and character of the whole head, as well as in the particular features,—the inclination of the facial line being more dependent on the prominence of the upper jaw and frontal sinuses than on the general form of the head. The ancients were impressed with the intellectual air exhibited by the open facial angle: for we find in all their statues of legislators, sages, and poets, an angle of at least 90°, and in those of heroes and superhuman natures it is as high as 100°. This angle, according to Camper, never existed in nature; and yet he conceives it to be the *beau idéal* of the human countenance, and to have been the ancient model of beauty. It was, more probably, the model of superior intellectual endowment, although ideas of beauty might have been connected with it. Every nation forms its notions of beauty, derived from this source, chiefly from the facial angle to which it is accustomed. With the Greeks it was large, and therefore the vertical facial line was highly estimated. For the same reason, it is pleasing to us; but such would not be the universal impression. Savage tribes on our own continent have preferred the pyramidal shape of the head, and made use of every endeavour, by unnatural compression in early infancy, to produce it; whilst others, not satisfied with the natural shape of the frontal bone, have forced back the forehead, either by applying a flat piece of board to it, like the Indians of our own continent, or by iron plates, like the inhabitants of Arracan. By this practice the Caraibs are said to be able to see over their heads.

M. Daubenton,[3] again, endeavoured, by taking the *occipital line* and *angle*, to measure the differences between the skulls of man and ani-

[1] Prichard's Physical History of Mankind, i. 288, 3d edit., Lond., 1836.
[2] Catalogue of Skulls of Man, &c., 3d edit., Philad., 1849.
[3] Mémoires de l'Académie des Sciences de Paris, p. 568, Paris, 1764.

mals. A line is drawn from the posterior margin of the foramen magnum of the occipital bone to the inferior margin of the orbit, and another from the top of the head to the space between the occipital condyles. In man, these condyles, as well as the foramen magnum, are so situate, that a line drawn perpendicular to them will be a continuation of the vertebral column; but in animals they are placed more or less obliquely; the perpendicular will, therefore, necessarily be thrown farther forward, and the angle be rendered more acute.[1] Blumenbach says, that Daubenton's method may be adapted to measure the degrees of comparison betwixt man and brutes, but not varieties of national character; for he found it even different in the skulls of two Turks, and three Ethiopians. The methods of Camper and Daubenton combined were, also, insufficient to indicate the varieties in national and individual character. He accordingly describes a new method,—which he calls *norma verticalis*.[2] It consists in selecting two bones; the frontal from those of the cranium, and the superior maxillary from those of the face; comparing these with each other, by regarding them vertically, placing the great convexity of the cranium directly before him, and marking the relative projections of the maxillary bone beyond the arch of the forehead. The Asiatic Georgian is found to be characterized by the great expanse of the upper and outer part of the cranium, which hides the face. In the Ethiopian, the narrow, slanting forehead permits the face to appear, whilst the cheeks and jaws are compressed laterally and elongated in front; and in the Tungoose, the maxillary, malar, and nasal bones are widely expanded on each side; and the two last rise to the same horizontal level with the space between the frontal sinuses—the glabella. Blumenbach's method, however, only affords us the comparative dimensions of the two bones in one direction. It does not indicate the depth of either, or their comparative areas. The view thus obtained is, therefore, partial.

Finding the inapplicability of other methods to the greater part of the animal creation—to birds, reptiles, and fishes, for example—M. Cuvier[3] suggested a comparison between the areas of the face and cranium under the vertical section of the head. The result of his observations is—that, in the European, the area of the cranium is four times that of the face, excluding the lower jaw. In the Calmuck, the area of the face is one-tenth greater than in the European; in the negro, one-fifth, and in the sapajou, one-half. In the mandril, the two areas are equal; and, in proportion as we descend in the scale of animals, the area of the face gains over that of the cranium; in the hare, it is one-third greater; in the ruminant animals double; in the horse, quadruple, &c.; so that the intelligence of the animal appeared

[1] By some writers, Daubenton's method is said to consist of "a line drawn from the posterior margin of the occipital foramen to the inferior margin of the orbit; and another drawn horizontally through the condyles of the occipital bone." It is obvious, that little or no comparative judgment of the cranium and face could be formed from this.

[2] Decad. Collectionis suæ Craniorum diversarum Gentium; and De Gener. Human. Var. Nativ., edit. 3a, Gotting., 1795.

[3] Leçons d'Anatomie Compar., No. viii. art. i. tom. ii. p. 1.

to be greater or less as the preponderance of the area of the face over that of the skull diminished or increased.

The truth, according to Sir Charles Bell,[1] is, that the great difference between the bones of the cranium and face in the European and negro is in the size of the jaw-bones. In the negro, these bear a much greater proportion to the head and to the other bones of the face than in the European; and the apparent size of the bones of the negro face was discovered to proceed solely from the size and shape of the jaw-bones; whilst the upper bones of the face, and, indeed, all that had no relation to the teeth and to mastication, were less than those of the European skull.

Other methods, of a similar kind, have been proposed by naturalists, as Spigel,[2] Herder,[3] Mulder,[4] Walther,[5] Doornik,[6] Spix,[7] and Oken, but they are all insufficient to enable us to arrive at a satisfactory comparison.[8] Blumenbach asserts, that he found the facial and occipital angles nearly alike in three-fourths of known animals. Moreover, it by no means follows, that, in the same species, there should be a correspondence between the size of the cranium and face. In the European, the face may be unusually large; and yet the mental endowments may be brilliant. Leo X., Montaigne, Leibnitz, Racine, Haller, Mirabeau, and Franklin, had all large features.[9]

All these methods, again, are confined to the estimation of the size of the whole encephalon; whereas the brain, we have seen, is alone concerned in the intellectual and moral manifestations; although Gall includes the cerebellum. It has already been remarked, that no animal equals man in the developement of the cerebral hemispheres. In the ape they are less prominent; and below it in the scale of creation, they become less and less; the middle lobes are less arched downwards; and the posterior lobes are ultimately wanting, leaving the cerebellum uncovered; the convolutions are less and less numerous and deep, and the brain at length is found entirely smooth. The experiments of Rolando of Turin, and Flourens[10] of Paris, are likewise confirmatory of this function of the brain proper. These gentlemen experimented upon different portions of the encephalon, with the view of detecting their functions;—endeavouring, as much as possible, not to implicate any part except the one which was the subject of investigation; and they found, that if the cerebral hemispheres were alone removed, the animal was thrown into a state of stupor or lethargy;

[1] Anatomy of Expression, 3d edit., Lond., 1844.

[2] Lineæ Cephalometricæ Spigelii, in Spigel, De Human. Corpor. Fabric., i. 8.

[3] Nackenlinien (Lineæ nuchales Herderi), in Herder's Ideen zur Philosophie der Geschichte der Menschheit, Th. iii. S. 186, Tübing., 1806.

[4] Vorderhauptwinkel (Angulus sincipitalis Mulderi), in art. Kopflinien, in Pierer's Anat. Physiol. Real Wörterb., iv. 524, Leipz., 1821.

[5] Schädelwinkel (Angulus Cranioscopicus Waltheri), in Walther, Kritische Darstellung der Gallschen Anat. Physiol. Untersuch. des Gehirn und Schädelbaues, S. 108, Zürich, 1802.

[6] Wijsgeerig Natuurkundig Onderzoek aangande den Oorspronglikeu Mensch en de Oorspronglike Stammen van deszelfs Geslacht, Amsterd., 1808.

[7] Cephalogenesis, Monach., 1815.

[8] Oken, Lehrbuch der Zoologie, Abth. ii. S. 660. A description of all these methods is given by Choulant, in Pierer, loc. cit.

[9] Gall, Sur les Fonctions du Cerveau ii. 296.

[10] Recherches Exp rimentales sur le Système Nerveux, 2de édit., Paris, 1842.

was insensible to all impressions; to every appearance asleep, and evidently devoid of all intellectual and affective faculties. On the other hand, when other parts of the encephalon were mutilated—the cerebellum, for example—leaving the cerebral hemispheres uninjured, the animal was deprived of certain other faculties—that of regulating the movements, for instance—but retained its consciousness, and the exercise of all its senses.

M. Desmoulins,[1] in his observations on the nervous system of vertebrated animals, is in favour of a view, embraced by M. Magendie,[2] that the intellectual sphere of man and animals depends exclusively on the cerebral convolutions; and that an examination of the convolutions will exhibit the intellectual differences, not only between different species, but between individuals of the same species. According to him, the cerebral convolutions are numerous in animals in proportion to their intelligence; and, in animals of similar habitudes, have a similar arrangement. In the same species, they differ sensibly according to the degree in which the individuals possess the qualities of their nature:—for example, they vary in the fœtus and adult; are manifestly less numerous and smaller in the idiot; and become effaced in protracted cases of insanity. He farther remarks, that the morbid conditions of the encephalon, which occasion mental aberration, are especially such as act upon the convolutions; and that whilst apoplectic extravasation into the centre of the organ induces paralysis of sensation and motion, the slightest inflammation of the arachnoid membrane causes delirium. Hence, he deduces the general principle, that the number and perfection of the intellectual faculties are in a ratio with the extent of the cerebral surfaces. It would seem, however, from some experiments by M. Baillarger,[3] that the amount of intellectual developement in man, and in the various classes of animals, is far from being proportionate to the extent of surface presented by the brain of each. That of man, for instance, has, in proportion to its volume, a much less extent of surface than the brains of the lower mammalia; and the brain of the rabbit has, in proportion to its volume, an extent of surface two and a half times greater than that presented by the brain of man.

The view of M. Desmoulins, so far as regards the seat of the intellectual and moral faculties, accords with one to which attention must now be directed; and which has given rise to more philosophical inquiry, laborious investigation, and, it must be admitted, to more idle enthusiasm and intolerant opposition, than any of the psychological doctrines advanced in modern times: we allude to the views of M. Gall.[4] These are, 1st, That the intellectual and moral faculties are innate. 2dly, That their exercise or manifestation is dependent upon organization. 3dly, That the encephalon is the organ of all the appetites, feelings, and faculties; and, 4thly, That the encephalon is composed of as many particular organs as there are appetites, feelings, and faculties, differing essentially from each other.

[1] Anatomie des Systèmes Nerveux des Animaux à Vertèbres, Paris, 1825.
[2] Précis Élémentaire, edit. cit., i. 185.
[3] Revue Médicale, Mai, 1845.
[4] Sur les Fonctions du Cerveau, Paris, 1825.

The importance of Gall's propositions; the strictly physiological direction they have taken—the only one, as we have said, which appears likely to aid us in our farther acquaintance with the psychology of man—require that the physiological student should have them placed before him as they emanated from the author. The work of Gall on the functions of the encephalon comprises, however, six octavo volumes, not distinguished for unusual method or clearness of exposition. Fortunately, the distinguished biologist, M. Adelon, to whom we have so frequently referred, has spared us the necessity of a tedious and difficult analysis, by the excellent and impartial view he has given in the *Dictionnaire de Médecine*,[1] which has since been transferred to his *Physiologie de l'Homme;* both being abridgments of the *Analyse d'un Cours du Dr. Gall*, published by him in 1808.

The foundation of this doctrine is, that the encephalon is not a single organ, but is composed of as many nervous systems as there are primary and original faculties of the mind. In the view of Gall, it is a group of several organs, each of which is concerned in the production of a special moral act; and, according as the encephalon of an animal contains a greater or less number of organs, and of a greater or less degree of developement, the animal has, in its moral sphere, a greater or less number of, or more or less active, faculties. In like manner, as there are as many sensorial nervous systems and organs of sense as there are external senses, so there are, it is maintained, as many encephalic nervous systems as there are special moral faculties or internal senses. Each moral faculty has, in the encephalon, a nervous part concerned in its production; as each sense has its special nervous system; the sole difference being, that the nervous systems of the senses are separate and distinct, whilst those of the encephalon are crowded together in the small cavity of the cranium, and appear to form but one mass.

The proofs adduced by Gall[2] in favour of his proposition are the following:—1st. It has been established as a principle, that differences in the psychology of man and animals correspond to varieties in the structure of the encephalon, and that the latter are dependent on the former. Now, differences of the encephalon consist less in changes of the general form of the organ, than in parts, which are present in some and not in others; and if the presence or absence of such parts is the cause why certain animals have a greater or less number of faculties than others, they ought certainly to be esteemed special organs of such faculties. 2dly. The intellectual and moral faculties are multiple. This every one admits. Each, consequently, ought to have its special organ; and the admission of a plurality of intellectual moral faculties must induce that of a plurality of encephalic organs, in the same manner as each external sense has its proper nervous system. 3dly. In different individuals of the same species,—in different men,—much psychological variety is observable. The cause of this is doubtless in the encephalon; but we can hardly ascribe it to a difference in the

[1] Art. Encéphale (Physiologie), Paris, 1823, and art. Facultés de l'Esprit et de l'Ame, &c., in Dict. de Médecine, viii. 469, Paris, 1823.

[2] Op. cit., ii. 394.

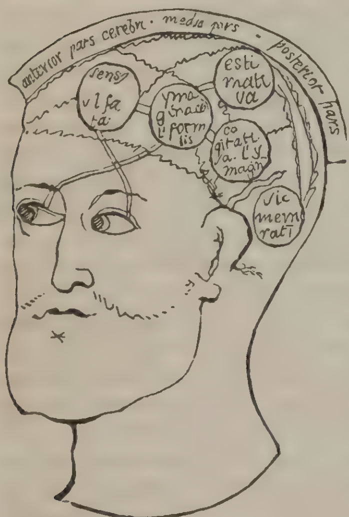
general shape of the organ, which is sensibly the same. It is owing rather to differences in its separate parts. Are not such parts, therefore, he asks, distinct nervous systems? 4thly. In the same individual—in the same man—the intellectual and affective faculties have never the same degree of activity; whilst one predominates, another may be feeble. Now, this fact, which is inexplicable under the hypothesis, that the encephalon is a single organ, is readily intelligible under the theory of the plurality of organs. Whilst the encephalic part, which is the agent of the one faculty, is proportionably more voluminous or more active, that which presides over the other is less so. Why, he asks, may not this happen with the encephalic organs, as with the other organs of the body,—the senses, for example? Cannot one of these be feeble, and the other energetic? 5thly. In the same individual, all the faculties do not appear, nor are they all lost at the same period. Each age has its own psychology. How can we explain these intellectual and moral varieties according to age, under the hypothesis that the encephalon is a single organ? Under the doctrine of the plurality of encephalic organs, the explanation is simple. Each encephalic system has its special period of developement and decay. 6thly. It is a common observation, that when we are fatigued by one kind of mental occupation, we have recourse to another; yet it often happens, that the new labour, instead of adding to the fatigue experienced by the former, is a relaxation. This, Gall remarks, would not be the case if the encephalon were a single organ, and acted as such; but it is readily explicable under the doctrine of plurality of organs. It is owing to a fresh encephalic organ having been put in action. 7thly. Insanity is frequently confined to one single train of ideas, as in the variety called *monomania*, which is often caused by the constancy and tenacity of an original exclusive idea. This is frequently removed by exciting another idea opposed to the first, which distracts attention from it. Is it possible, Gall asks, to comprehend these facts under the hypothesis of unity of the encephalon? 8thly. Idiocy and dementia are often only partial, and it is not easy to conceive, under the idea of the unity of the encephalon, how one faculty remains amidst the abolition of all the others. 9thly. A wound or a physical injury of the encephalon frequently modifies but one faculty, paralyzing, or augmenting it, and leaving every other uninjured. 10thly, and lastly. Gall invokes the analogy of other nervous parts; and, as the great sympathetic, medulla oblongata, and medulla spinalis are—in his view at least—groups of special nervous systems, it is probably, he says, the same with the encephalon.

Such are the main arguments employed by Gall for proving, that the encephalon consists of a plurality of organs, each of which is concerned in the production of a special intellectual or moral faculty; and should they not carry conviction, it must be admitted that many of them are ingenious and forcible, and all merit attention.

It is a prevalent idea, that this notion of a plurality of organs is a fantasy, which originated with Gall. Nothing is more erroneous: he has adduced the opinions of numerous writers who preceded him, some of whom have given figures of the cranium, with the seats of the different organs and faculties marked upon it. To this list might be

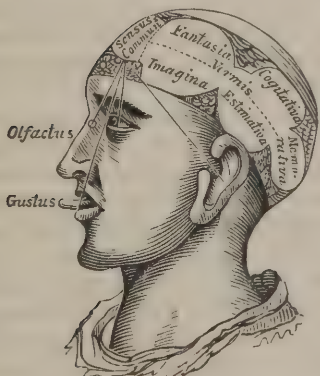
added numerous others. Aristotle, in whose works are found the germs of many discoveries and speculations, thought that the first or anterior ventricle of the brain, was the ventricle of *common sense;* because, from it, according to him, the nerves of the five senses branched off. The second ventricle, connected by a minute opening with the first, he designated as the seat of *imagination, judgment* and *reflection;* and the third, as a storehouse into which the conceptions of the mind, digested in the second ventricle, were transmitted for retention and accumulation; he regarded it as the seat of *memory.* Bernard Gordon, in a work written in 1296, gives nearly the same account of the brain. It contains, he says, three cells or ventricles. In the anterior part of the first lies *common sense;* the function of which is to take cognizance of the various forms and images received by the several senses. In the posterior part of the first ventricle he places *phantasia;* and in the anterior part of the second, *imaginativa;* in the posterior part of the middle lies *estimativa.* It would be a waste of time and space, to adduce the absurd notions entertained by Gordon on this subject. He thinks there are three faculties or virtues—*imaginatio, cogitatio,* and *memoria*—each of which has a special organ engaged in its production.

Fig. 324.



Old Phrenological Head.

Fig. 325.



Phrenological Head by Dolci, A. D. 1562.

For many centuries it was believed, that the cerebrum was the organ of *perception,* and the cerebellum that of *memory.* Albert the Great, in the thirteenth century, sketched a head on which he represented the seat of the different intellectual faculties. In the forehead and first ventricle he placed *common sense* and *imagination;* in the second *intelligence* and *judgment;* and in the third, *memory* and the *motive force.* The head in the margin (Fig. 324) is from an old sketch contained in the *Book Rarities* of the University of Cambridge. Servetus conceived, that the two anterior cerebral cavities are for the reception of the images of external objects; the third is the seat of thought; the aqueduct of Sylvius, the seat of the soul; and the fourth ventricle that of memory. In 1491, Peter Montagnana published an engraving, in which were represented the seat of the *sensus communis,* a *cellula imaginativa, cellula estimativa* seu *cogitativa,* a *cellula memorativa,* and a

cellula rationalis. A head by Ludovico Dolci exhibits a similar arrangement. (Fig. 325.)[1]

The celebrated Dr. Thomas Willis, in 1681, asserted, that the corpora striata are the seat of perception; the medullary part of the brain that of *memory* and *imagination;* the corpus callosum that of *reflection;* and the cerebellum furnished the vital spirits necessary for the involuntary motions.[2] It would appear, too, that Swedenborg, half a century before the promulgation of Gall's theory, maintained the doctrine, that every man is born with a disposition to all sorts of evil, which must be checked by education, and, as far as possible, rooted out; and that the degree of success or failure in this respect would be indicated by the shape of the skull. "The peculiar distinctions of man, will and the understanding," he argued, "have their seats in the brain, which is excited by the fleeting desires of the will, and the ideas of the intellect. Near the various spots where these irritations produce their effects, this or that part of the brain is called into a greater or less degree of activity, and forms along with itself corresponding parts of the skull."[3] This view, that exercise of the encephalic organs occasions their developement in bulk, and want of due exercise their decrease, is now maintained by many phrenologists; but denied by others.

The above examples are sufficient to show, that the attempt to assign faculties to different parts of the brain; and, consequently, the belief, that the brain consists of a plurality of organs, had been long indulged by anatomists and philosophers. The views of Gall are resuscitations of the old; but resembling them little more than in idea. Those of the older philosophers were the merest fantasies, unsupported by observation: the speculations of the modern physiologists have certainly been the result of long and careful investigation, and deep meditation. Whilst, therefore, we may justly discard the former, the latter are worthy of careful and unprejudiced examination.

Admitting, with M. Gall, the idea of the plurality of organs in the encephalon, the inquiry would next be,—how many special nervous systems are there in that of man, and what are the primary intellectual and moral faculties over which they preside? This Gall has attempted. To attain this double object, he had two courses to adopt;—either, first to indicate anatomically the nervous systems that constitute the encephalon; and then to trace the faculties of which they are the organs; or, contrariwise, to point out first the primary faculties, and afterwards to assign to each an organ or particular seat. The first course was impracticable. The encephalic organs are not distinct, isolated: and if they were, simple inspection could not indicate the faculty over which they preside, any more than the appearance of a nerve of sense could indicate the kind of sensation for which it is destined. It was only, therefore, by observing the faculties, that he could arrive at a specification of the primary encephalic organs. But here, again, a source of difficulty arose. How many primary intellectual and

[1] See Burton's Anatomy of Melancholy, 11th edit., i. 32, Lond., 1813; and Margarita Philosophica, lib. ix. cap. 40, Basil., 1508, cited by Dr. John Redman Coxe, in Dunglison's American Medical Intelligencer, i. 58, Philad., 1838.

[2] Gall, Sur les Fonctions du Cerveau, ii. 350, Paris, 1835.

[3] Dr. Sewall, Examination of Phrenology, 2d edit., p. 14, Boston, 1839.

moral faculties are there in man? and what are they? The classifications of the mental philosophers,—differing, as we have seen they do, so intrinsically and essentially from each other,—could lead him to no conclusion. He first, however, followed the views on which they appeared to be in accordance; and endeavoured to find particular organs for the faculties of *memory*, *judgment*, *imagination*, &c. But his researches in this direction were fruitless. He, therefore, took for his guidance the common notions of mankind; and having regard to the favourite occupations, and different vocations of individuals; to those marked dispositions, which give occasion to the idea, that a man is born a *poet*, *musician*, or *mathematician*, he carefully examined the heads of such as presented these predominant qualities, and endeavoured to discover in them such parts of the encephalon as were more prominent than usual, and might be considered as special nervous systems,—organs of those faculties. After multitudinous empirical researches on living individuals, on collections of crania, and casts made for the purpose; attending particularly to the heads of such as had one of their faculties predominant, and who were, as he remarks, *geniuses* on one point,—to the maniac, and the monomaniac;—after a sedulous study, likewise, of the heads of animals, comparing especially those that have a particular faculty with such as have it not, in order to see if there did not exist in the encephalon of the former some part which was wanting in that of the latter; by this entirely experimental method, he ventured to specify, in the encephalon of animals and man, a certain number of organs; and, in their psychology, as many faculties, truly primary in their character.

But, in order that such a mode of investigation be applicable, it must be admitted, 1st. That one of the elements of the activity of a function is the developement of its organ. 2dly. That the encephalic organs end, and are distinct, at the surface of the encephalon. And 3dly. That the cranium is moulded to the encephalon, and is a faithful index of its shape; for it is, of course, through the skull and the integuments covering it, that Gall attempts, in the living subject, to appreciate the state of the encephalon.

Within certain limits, these positions are true. In the first place, we judge of the activity of a function, by the size of the organ that executes it: the greater the optic nerve, the more acute we expect to find the sense of sight. In the second place, according to the anatomical theory of Gall, the encephalic convolutions are the final expansions of the encephalon: if we trace back the original fasciculi, which, by their terminations, form the hemispheres of the brain, they are observed to increase gradually in size in their progress towards the circumference of the organ, and to end in the convolutions. Lastly, to a certain extent the cranium is moulded to the encephalon; and participates in all the changes which the latter undergoes at different periods of life and in disease. For example, during the first days after the formation of the encephalon of the fœtus, the cranium is membranous, and has exactly the shape of that viscus. On this membrane, ossific points are deposited, so that, when the membrane has become bone, the cranium has still the shape of the encephalon. In short, nature having made the skull to contain the encephalon, has fitted the

one to the other, and this so accurately, that its internal surface exhibits sinuosities corresponding to the vessels that creep on the surface; and digitations corresponding to the encephalic convolutions. The encephalon, in fact, rigidly regulates the ossification of the cranium; and when, in the progress of life, it augments, the capacity of the cranium is augmented likewise; not by the effect of mechanical pressure, but owing to the two parts being catenated in their increase and nutrition. This remark applies not only to the skull and encephalon, regarded as a whole, but to their separate parts. Certain portions of the encephalon are not developed simultaneously with the rest of the organ; and the same thing happens to the portions of the skull that invest them. The forehead, for example, begins to be developed after the age of four months; but the inferior occipital fossæ do not increase in proportion until the period of puberty. Again; when the encephalon fades and wastes in advanced life, the cavity of the cranium contracts, and its ossification takes place on a less and less outline. In advanced life, however, according to Gall, the correspondence between the encephalon and the inner table of the skull is alone maintained; the table appearing to be a stranger to all nutritive movement, and preserving its dimensions. Lastly, the cranium partakes of all the variations experienced by the encephalon in disease. If the latter be wanting, as in the acephalous monster, the cranium is wanting also. If a portion of the encephalon exists, the corresponding portion of the cranium exists. If the encephalon is smaller than natural, as in the idiot, the cranium is also. If, on the contrary, it is distended by hydrocephalus, the cranium has a considerable capacity; and this, not owing to a separation, at the sutures, of the bones composing it, but to ossification taking place on a larger outline. If the encephalon be much developed in any one part, and not in another, the cranium is protuberant in the former,—restricted in the latter; and lastly, in cases of mania, the cranium is often affected, being, for example, unusually thick, dense, and heavy.

These reasons, adduced by Gall, may justify the admission, that, within certain limits, the skull is moulded to the encephalon; and, if this be conceded, the method followed by him of specifying the organs of the mental faculties may be conceived practicable.

Such is the basis of the system of *craniology* proposed by Gall. It has also been called *cranology*, *organology*, *phrenology*, and *cranioscopy:* although, strictly speaking, it is by *cranioscopy* that we acquire a knowledge of *craniology*,—the art of prejudging the intellectual and moral aptitudes of man and animals, from an examination of the cranium. It is, of course, limited in its application. Gall admits, that it is not available in old age, owing to the physiological fact before stated,—that the external table of the skull is no longer modified by the changes, that happen to the encephalon; and he acknowledges, that its employment is always difficult, and liable to errors. We cannot, for example, touch the cranium directly; for it is covered by hair and integument. The skull is made rough, in parts, by muscular impressions; and these roughnesses must not be confounded with what are termed "*protuberances*,"—prominences formed by a corresponding developement of the encephalon. In this respect, craniology presents more difficulties

in animals, owing to their heads being more covered with muscles, and from the inner table of the skull being, alone, in contact with the encephalon beneath. Other errors may be incurred from the frontal and superior longitudinal sinuses; and from the possible separation of the hemispheres at the median line. The difficulty is, of course, extremely great in appreciating the parts of the encephalon, that are situate behind the eyes; and craniology must be entirely inapplicable to those encephalic organs that terminate at its base.

Gall has taken especial pains to remark, that by craniology we can only prejudge the dispositions of men, not their actions; and can appreciate but one of the elements of the activity of organs—their

Fig. 326.

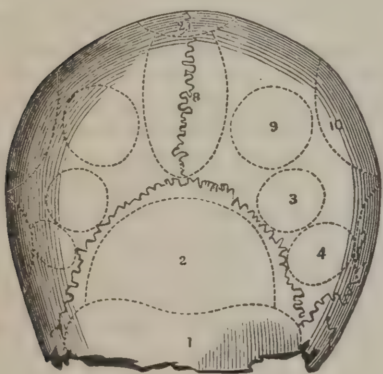


Fig. 327.

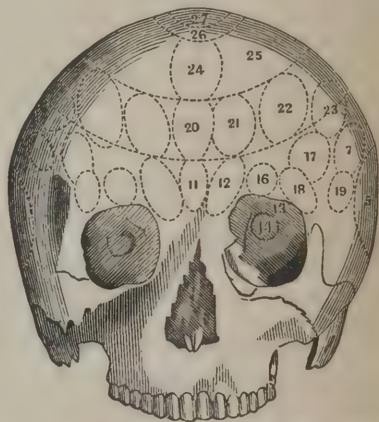
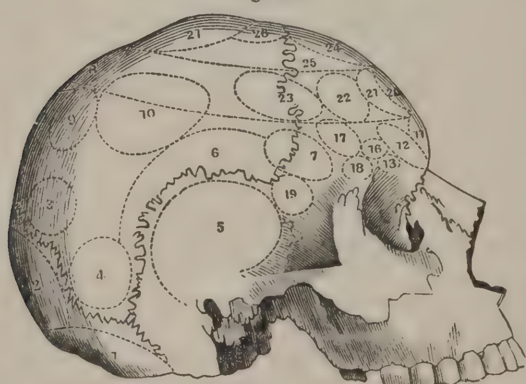


Fig. 328.



Phrenological Organs according to Gall.

size,—not what belongs to their intrinsic activity, and to the impulse or spring they may receive from the temperament or general formation. Setting out, however, with the principle, that the predominance of a faculty is in a great measure dependent on the developement of the portion of the encephalon which is its organ, he goes so far as to par-

ticularize, in this developement, what is owing to the length of the encephalic fibres, and what to their breadth; referring the activity of the faculty to the former, and its intensity to the latter. In applying cranioscopy to animals, he observes, that the same encephalic organ frequently occupies parts of the head, that seem to be very different, on account of the difference between station in animals and man, and of the greater or less number of systems, that compose their encephalon.

The following are the encephalic organs enumerated by Gall, with the corresponding faculties:—the numbers corresponding with those of the above illustrations.

1. *Instinct of generation, of reproduction; amativeness. Instinct of propagation; venereal instinct.* (*German.*) Zeugungstrieb, Fortpflanzungstrieb, Geschlechtstrieb.	Seated in the cerebellum. It is manifested at the surface of the cranium by two round protuberances, one on each side of the nape of the neck.
2. *Love of progeny; philoprogenitiveness.* (*G.*) Jungenliebe, Kinderliebe.	Indicated at the external occipital protuberance.
3. *Attachment, friendship.* (*G.*) Freundschaftsinn.	About the middle of the posterior margin of the parietal bone; anterior to the last.
4. *Instinct of defending self and property; love of strife and combat; combativeness; courage.* (*G.*) Muth, Raufsinn, Zanksinn.	Seated a little above the ears; in front of the last, and towards the mastoid angle of the parietal bone.
5. *Carnivorous instinct; inclination to murder; destructiveness; cruelty.* (*G.*) Wurgsinn, Mordsinn.	Greatly developed in all the carnivorous animals; forms a prominence at the posterior and superior part of the squamous surface of the temporal bone, above the mastoid process.
6. *Cunning; finesse; address; secretiveness.* (*G.*) List, Schlauheit, Klugheit.	Above the meatus auditorius externus, upon the sphenoidal angle of the parietal bones.
7. *Desire of property; provident instinct; cupidity; inclination to robbery; acquisitiveness.* (*G.*) Eigenthumssinn, Hang zu stehlen, Einsammlungssinn, Diebsinn.	Anterior to that of cunning, of which it seems to be a prolongation, and above that of mechanics, with which it contributes to widen the cranium, by the projection which they form at the side of the frontal bone.
8. *Pride; haughtiness; love of authority; elevation.* (*G.* Stolz, Hochmuth, Höhensinn, Herrschsucht.	Behind the top of the head, at the extremity of the sagittal suture, and on the parietal bones.
9. *Vanity; Ambition; love of glory.* (*G.*) Eitelkeit, Ruhmsucht, Ehrgeitz.	Situate at the side of the last, near the posterior internal angle of the parietal bones.
10. *Circumspection; foresight.* (*G.*) Behutsamkeit, Vorsicht, Vorsichtigkeit.	Corresponds to the parietal protuberances.
11. *Memory of things; memory of facts; sense of things; educability; perfectibility; docility.* (*G.*) Sachgedächtniss, Erziehungsfähigkeit, Sachsinn.	Situate at the root of the nose, between the two eyebrows, and a little above them.
12. *Sense of locality; sense of the relation of space; memory of places.* (*G.*) Ortsinn, Raumsinn.	Answers to the frontal sinuses, and is indicated externally by two prominences at the inner edge of the eyebrows, near the root of the nose, and outside the organ of memory of things.

13. *Memory of persons; sense of persons.* (*G.*) Personensinn.	At the inner angle of the orbit.
14. *Sense of words; sense of names; verbal memory.* (*G.*) Wortgedächtniss, Namensinn.	Situate at the posterior part of the base of the two anterior lobes of the brain, on the frontal part of the bottom of the orbit, so as to make the eye prominent.
15. *Sense of spoken language; talent of philology; study of languages.* (*G.*) Sprachforschungssinn, Wortsinn, Sprachsinn.	Also at the top of the orbit, between the preceding and that of the knowledge of colour.
16. *Sense of the relations of colour; talent of painting.* (*G.*) Farbensinn.	The middle part of the eyebrows; encroaching a little on the forehead.
17. *Sense of the relations of tones; musical talent.* (*G.*) Tonsinn.	A little above and to one side of the last; above the outer third of the orbitar arch.
18. *Sense of the relations of numbers; mathematics.* (*G.*) Zahlensinn.	On the outside of the organ of the sense of the relations of colour, and below the last.
19. *Sense of mechanics; sense of construction; talent of architecture; industry.* (*G.*) Kunstsinn, Bausinn.	A round protuberance at the lateral base of the frontal bone, towards the temple, and behind the organs of music and numbers.
20. *Comparative sagacity.* (*G.*) Vergleichender Scharfsinn.	At the middle and anterior part of the frontal bone, above that of the memory of things.
21. *Metaphysical penetration; depth of mind.* (*G.*) Metaphysischer Tiefsinn.	In part, confounded with the preceding. Indicated, at the outer side of this last, by two protuberances, which give to the forehead a peculiar hemispherical shape.
22. *Wit.* (*G.*) Witz.	At the lateral and outer part of the last; and giving greater width to the frontal prominences.
23. *Poetical talent.* (*G.*) Dichtergeist.	On the outer side of the last; divided into two halves by the coronal suture.
24. *Goodness; benevolence; mildness; compassion; sensibility; moral sense; conscience; bonhommie.* (*G.*) Gutmüthigkeit, Mitleiden, moralischer Sinn, Gewissen.	Indicated by an oblong prominence above the organ of comparative sagacity; almost at the frontal suture.
25. *Imitation; mimicry.* (*G.*) Nachahmungssinn.	At the outer side of the last.
26. *God and religion; theosophy.* (*G.*) Theosophisches Sinn.	At the top of the frontal bone and at the superior angles of the parietal bones.
27. *Firmness; constancy; perseverance; obstinacy.* (*G.*) Stetigkeit, fester Sinn.	The top of the head; at the anterior and most elevated part of the parietal bones.

The first nineteen of these, according to Gall, are common to man and animals: the remaining eight man possesses exclusively. They are, consequently, the attributes of humanity.

Dr. Spurzheim,[1] a fellow-labourer with Gall, who accompanied him in his travels, and was associated with him in many of his publications, added other faculties, so as to make the whole number thirty-five; but they were not embraced by Gall; indeed, several of the positions of Spurzheim are repudiated by Gall's followers.[2] The organs admitted by Spurzheim are given on the next page: the numbers correspond with those of the illustrations.

On the situation of the different encephalic organs, Gall remarks,—

[1] Phrenology, Amer. edit., Boston, 1833.
[2] Elliotson, Human Physiology, p. 384, and 1147, London, 1840.

1st. That those which are common to man and animals are seated in parts of the encephalon common to both:—at the posterior, inferior, and anterior inferior, portions. On the contrary, those, that are exclusive to man, are situate in parts of the encephalon that exist only in

Fig. 329.

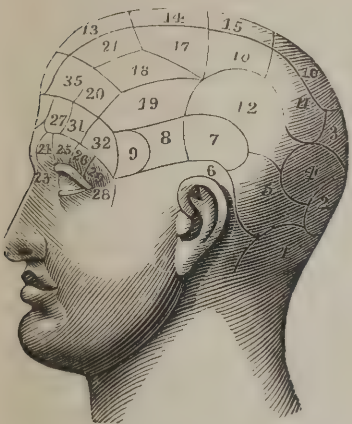


Fig. 330.

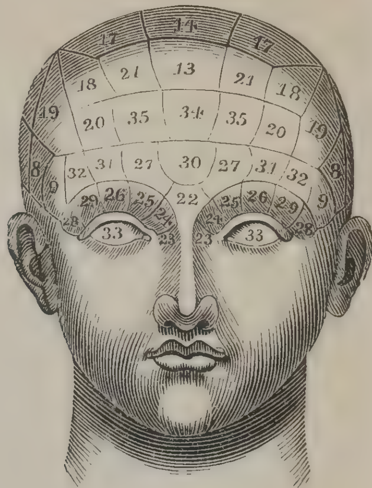
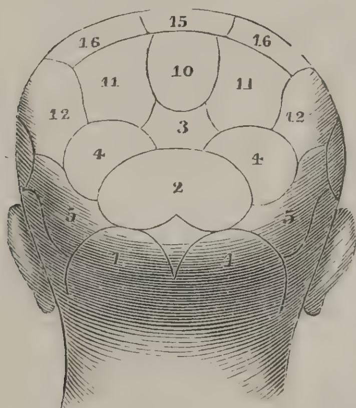


Fig. 331.



Phrenological Organs according to Spurzheim.

1. Amativeness. 2. Philoprogenitiveness. 3. Inhabitiveness. 4. Adhesiveness or Attachment. 5. Combativeness. 6. Destructiveness. 7. Constructiveness. 8. Acquisitiveness. 9. Secretiveness. 10. Self-Esteem. 11. Love of Approbation. 12. Cautiousness. 13. Benevolence. 14. Veneration. 15. Firmness. 16. Conscientiousness or Justice. 17. Hope. 18. Marvellousness. 19. Wit. 20. Ideality. 21. Imitation. 22. Individuality. 23. Form. 24. Size. 25. Weight and Resistance. 26. Colour. 27. Locality. 28. Numeration. 29. Order. 30. Eventuality. 31. Time. 32. Melody or Tune. 33. Language. 34. Comparison. 35. Causality.

him;—in the anterior superior parts, which form the forehead. 2dly The more indispensable a faculty, and the more important to the animal economy, the nearer is its organ to the median line, and to the base of the encephalon. 3dly, and lastly. The organs of the faculties,

that aid, or are similar to each other, are generally situate in proximity.

In his exposition of each of these organs, and of the reasons that induce him to assign it as the seat of a special faculty, he sets out,—first by demonstrating the necessity of the faculty, which he regards as fundamental and primary, and to which he assigns a special nervous system or organ in the encephalon. 2dly. He endeavours to show, that this faculty is really primary. He considers it to be such, whenever psychical facts show, that it has its exclusive source in organization; for example, when it is not common to all animals and sexes; when, in the one possessing it, it does not exhibit itself in a ratio with the other faculties; has its distinct periods of developement and decrease; and does not, in this respect, coincide with the other faculties; when it can be exerted, be diseased, and continue sound alone, or be transmitted alone from parent to child, &c. Lastly, he points out the part of the encephalon, which he considers to be its organ, founding his decision on numerous empirical observations of the encephalon of men and animals, that have possessed, or been devoid of, the faculty and organ in question; or have had them in unequal degrees of developement.

It is impossible, in a work of this kind, to exhibit all the views of Gall, and the arguments he has adduced in favour of the existence of his twenty-seven faculties. The selection of one—the *instinct of generation*—will be sufficient to show how he treats of the whole. Gall's *instinct of generation* is that, which, in each animal species, attracts the individuals of different sexes towards each other for the purpose of effecting the work of reproduction. The *necessity* for such an impulse for the general preservation of animals is manifest. It is to the continuance of the species what the sensation of hunger is to that of the individual. Again: it is certainly *primary* and *fundamental*, for it is independent of all external influence. It does not make its appearance until puberty, and disappears long before other faculties. In many animals it returns periodically. In each animal species, and in each individual, it has a special and different degree of energy; although external circumstances may be much the same in all, or at least may not present differences in any manner proportionate to those of the instinct. It may be either alone active, amidst the languor of other faculties; or may be alone languishing. Lastly, it cannot be referred to the genital organs, for it has been observed in children, whose organs have not been developed; it has frequently continued to be felt in eunuchs; and has been experienced by females, who, owing to original monstrosity, have had neither ovary [?] nor uterus. The part of the encephalon which is the *organ* of the instinct, is, according to Gall, the *cerebellum*. His reasons for this belief are the following. 1st. In the series of animals, a cerebellum exists only in those which are reproduced by copulation, and which, consequently, must have the instinct in question. 2dly. There is a perfect coincidence between the periods at which the cerebellum becomes developed, and the appetite appears. In infancy, it does not exist; and the organ is therefore small. 3dly. In every species of animal and in every individual, there is a ratio between the size of the cerebellum and the energy of the inclination. In males, in whom it is generally more imperious, the cerebellum is larger. 4thly. A ratio

exists between the structure of the cerebellum and the kind of generation. In oviparous animals, for instance, the cerebellum is smaller at its median part; and it is only in the viviparous, that hemispheres exist. 5thly. A similar ratio obtains between the cerebellum and external genital organs. If the latter are extirpated at an early age, the developement of the cerebellum is arrested, and it continues small for the remainder of life. Neighbouring parts, which are attributes of the male sex, as the horns of the stag, and the crest of the cock, are often similarly stunted. On the other hand, the cerebellum, in its turn, exerts an intimate influence on the venereal appetite; and modifies the external genital organs. Injuries of the cerebellum either render the person impotent, or excite erotic mania. In nymphomania, the patient often complains of acute pain in the nape of the neck; and this part is more tumid and hot in animals at the rutting season. Gall asserts, that he had noticed in birds, that the cerebellum is not the same in size and excitement during the season of love as at other times; and he affirms, that if erection be observed in those who are hanged, or in consequence of the application of a blister or a seton to the nape of the neck, or of the use of opium, or in such as are threatened with apoplexy, especially when the apoplexy is cerebellous,[1] or during sleep, the effect is, in all these cases, owing to congestion of blood in the brain in general, and in the cerebellum in particular. From these data Gall concludes, that the cerebellum is the organ of the instinct of reproduction; and he remarks, that as this organ presides over one of the most important faculties, it is situate on the median line; and at the base of the skull. In this manner, he proceeds, with more or less success, in his investigation of the other cerebral organs and faculties.

But Gall does not restrict himself to the physiological applications of his system. He endeavours to explain the differences that exist between him and other philosophers. He rejects the primary faculties of *instinct*, *intelligence*, *will*, *liberty*, *reason*, *perception*, *memory*, *judgment*, &c., of the metaphysician, as mere generalizations of the mind, or common attributes of the true primary faculties. Whilst, in the study of physics, the general and special qualities of matter have been carefully distinguished, and the latter have been regarded as alone deciding the particular nature of bodies, the metaphysician, says Gall, has restricted himself to general qualities. For example, it is asserted, that "to *think* is to *feel*." Thought is, doubtless, a phenomenon of sensibility; but it is a sensitive act of a certain kind. To adhere rigidly to this expression, says Gall, is but to express a generality, which leaves us in as much ignorance as to what thought is, as we should be of a quadruped or bird, by saying that it is an animal; and as, to become acquainted with such animals, their qualities must be specified, so to understand thought, the kind of sensation that constitutes it must be specified. *Instinct*, according to him, is a general expression,

[1] A case of Arachnitis Cerebelli—in which there was genital excitement—is reported by the author, in Lond. Med. Rep. for Oct., 1822. For cases of cerebellous disease, without genital excitement, see Duplay, in Archives Générales de Médecine, Nov., 1836; Müller's Elements of Physiology, by Baly, 1st edit., p. 833, Lond., 1838; and Longet, Anat. et Physiol. du Système Nerveux, tom. i. Paris, 1842; and Traité de Physiologie, ii. 267, Paris, 1850.

denoting every kind of internal impulse; and, consequently, there must be as many instincts as there are fundamental faculties. *Intelligence* is likewise a general expression, designating the faculty of knowledge; and as there are many instincts, so there are many kinds of intelligence. Philosophers, he thinks, have erroneously ascribed instinct to animals, and intelligence to man. All animals have, to a certain extent, intelligence; and in man many faculties are instincts. Neither is the *will* a fundamental faculty. It is only a judgment formed amongst several motives, and the result of the concourse of actions of several faculties. There are as many desires as faculties, but there is only one will, which is the product of the simultaneous action of the intellectual forces. So that the will is frequently in opposition to the desires. The same may be said of *liberty* and *reason;* to the former applies what has been remarked of the will, and the latter is only the judgment formed by the superior intellectual faculties. In this respect, however, he remarks, it must not be confounded with intelligence: many animals are intelligent, but man alone is rational.

On the other hand, what are termed, in the intellect, *perception*, *memory*, *judgment*, *imagination*, &c., are attributes common to all the intellectual faculties; and cannot, consequently, be considered primary faculties. Each faculty has its perception, memory, judgment, and imagination; and, therefore, there are as many kinds of perception, memory, judgment, and imagination, as there are primary intellectual faculties. This is so true, says Gall, that we may have the memory and the judgment perfect upon one point, and totally defective upon another. The memory of musical tones, for instance, is not the same as that of language; and he who possesses the one may not have the other. The imaginations, again, of the poet, musician, and philosopher, differ essentially from each other. These faculties are, therefore, according to him, nothing more than different modes of the activity of all the faculties. Each faculty perceives the notion to which it has been attracted, or has *perception;* each preserves and renews the recollection of this notion, or has *memory*. All are disposed to act without being excited to action from without, when the organs are largely developed, or have considerable intrinsic activity: this gives rise to *imagination;* and, lastly, every faculty exerts its function with more or less perfection, whence results *judgment*. *Attention*, in his view, is only the active mode of exercise of the fundamental faculties of the intellect; and being an attribute of all it cannot be called a primary faculty.

As regards the *affective faculties*, or what have been called the *passions* and *affections*, Gall, in the first place, asserts, that the term *passion* is faulty when used to indicate a primary faculty. It ought only to designate the highest degree of activity of any faculty. Every faculty requires to be put into action, and according to the degree of activity which it possesses, it is a *desire*, a *taste*, an *inclination*, a *want*, or a *passion*. If it be only of the medium energy, it is a *taste:* if extremely active, a *passion*. There may, consequently, be as many passions as there are faculties. We speak of a *passion for study*, or a *passion for music*, as we do of the *passion of love*, or of *ambition*. Gall objects, also, to the word *affection*, which, according to him, expresses only the

modifications presented by the primary faculties, according to the mode in which external and internal influences affect them. Some of these are common to all the faculties, as those of *pleasure* and *pain*. Every faculty may be the occasion of one or the other. Other affections are special to certain faculties; as *pretension*, which, he says, is an affection of *pride*, and *repentance* an affection of the moral sense. Finally, affections are *simple* or *compound: simple* when they only bear upon one faculty, as *anger*, which is a simple affection of the faculty of self-defence;—*compound*, when several faculties are concerned at the same time, as *shame*, which is an affection of the primary faculties of the *moral sense* and *vanity*.

Gall reproaches the moralists with having multiplied too much the number of primary affective faculties:—in his view, the modifications of a single faculty, and the combination of several, give rise to many sentiments, that are apparently different. For instance, the primary faculty of *vanity* begets *coquetry*, *emulation*, and *love of glory*. That of *self-defence* gives rise to *temerity*, *courage*, a *quarrelling spirit*, and *fear*. *Contempt* is the product of a combination of the faculties of *pride* and the *moral sense*, &c.

Lastly; as regards their psychical differences, Gall divides all men into five classes. *First.* Those in whom all the faculties of humanity predominate; and in whom, consequently, organization renders the developement of the mind and the practice of virtue easy. *Secondly.* Those in whom the organs of the animal faculties predominate; and who, being less disposed to goodness, need the aid of education and legislation. *Thirdly.* Those in whom all the faculties are equally energetic, and who may be either worthy, or great criminals, according to the direction they take. *Fourthly.* Those who, with the rest of the faculties nearly equal and mediocre, may have one predominant. *Fifthly*, and *lastly*. Those who have the faculties alike mediocre:—which is the most numerous class. It is rare, however, he remarks, that the characters and actions of men proceed from a single faculty. Most commonly, they are dependent upon the combination of several; and, as the possible combinations of so many faculties are almost innumerable, the psychical varieties of mankind must be extremely various. Again, as each of the many organs of the brain may have, in different men, a particular degree of developement and activity, seeing that each of the faculties, which are their products, has most commonly a particular shade in every individual; as these organs can establish between each other a great number of combinations; and as men, independently of the differences in their cerebral organization, which give rise to their *dispositions*, never cultivate and exert their faculties in an equal and similar manner, it may be conceived, that nothing ought to be more variable than the intellectual and moral characters of men; and we may thus explain, why there are no two men alike in this respect.

Such is a general sketch of the physiological doctrine of Gall, which we may sum up in the language of the author, in his *Revue Sommaire*, appended to his great work. "I have established, by a considerable number of proofs, as well negative as positive, and by the refutation of the most important objections, that the encephalon alone has the

immense advantages of being the organ of the mind. Farther researches on the measure of the degree of intelligence of man and animals have shown, that the encephala are more simple or more complex, as their instincts, desires, and faculties are more simple or more compound; that the different regions of the encephalon are concerned in different categories of function; and, finally, that the encephalon of every species of animal, and, consequently, that of man, constitutes an aggregation of as many special organs, as there are essentially different moral qualities and intellectual faculties in the man or animal. The moral and intellectual dispositions are innate. Their manifestation is dependent upon organization. The encephalon is the exclusive organ of the mind. Such are four incontestable principles, forming the whole physiology of the encephalon:"—and he adds;—"the detailed developement of the physiology of the encephalon has unveiled the deficiencies of the hypotheses of philosophers regarding the moral and intellectual powers of man; and has been the means of bringing to light a philosophy of man, founded on his organization, and, consequently, the only one in harmony with nature."[1]

It is impossible to enter, at length, into the various facts and hypotheses developed in the preceding exposition. The great points of doctrine in the system of Gall, are:—*First.* That the encephalon consists of a plurality of organs, each engaged in a separate, distinct office,—the production of a special intellectual or moral faculty. *Secondly.* That each of these organs ends at the periphery of the encephalon; and is indicated by more or less developement of the part; and *Thirdly.* That, by observation of the skull, we may be enabled to detect the protuberance, produced by such encephalic developement; and thus indicate the seat of the encephalic organs of the different faculties. It has been shown in the preceding history, that the notion of the plurality of organs has prevailed extensively in all ages; and whatever may be the merit of the arguments adduced by Gall on this subject, it is difficult not to conceive, that different primary faculties may have their corresponding organs. Simple inspection of the encephalon indicates that it consists of numerous parts, differing essentially in structure and appearance from each other; and it is but philosophical to presume, that these are adapted to equally different functions, although our acquaintance with the physiology of the organs may not be sufficiently extensive to enable us to designate them. Of the innate character of several of the faculties described by Gall, it is scarcely possible for us to admit a doubt. Take, for instance, the *instincts of generation* and of *love of progeny.* Without the existence of these, every animal species would soon be extinct. It seems fair, then, to presume, that these instincts or innate faculties may have encephalic organs specially concerned in their manifestation. Gall places them in the posterior part of the head,—the instinct of generation in the cerebellum; and his causes for so doing have been cited; yet, striking as his statement in regard to the encephalic seat of the instinct of generation seems to be, it has been contested by many physiologists,—by MM. Broussais, Foville, and Pinel-Grandchamp, Rolando, Flourens,

[1] Sur les Fonctions du Cerveau, vi. 500, Paris, 1825.

Desmoulins, Calmeil, and others; and, not only by argument, but by that which must be the test of the validity of the doctrines of the phrenologists,—direct experiment. It has been shown, indeed, that the genital excitement which is supposed by the followers of Gall to be seated in the cerebellum, can be equally produced by irritating the posterior column of the spinal marrow; and it would seem, that coincidence of disease of the spinal cord with affection of the genital organs is much more frequent.[1] According to Burdach, the proportion of cases of disease of the cerebellum, in which there is any manifest affection of the sexual organs, is really very small,—not above one in seventeen. Erection has frequently been observed in men after fracture or luxation of the spine; and in hanging, erection and ejaculation of sperm are not uncommon. Dr. Brown Sequard[2] affirms, that a transverse section of the cord in the guinea pig always produces erection and ejaculation; and the same occurs when the animal is asphyxiated, or if the cord be galvanized.

The results, too, of unprejudiced observation, as to the comparative size of the cerebellum in different animals, are by no means favourable to the phrenological doctrine. There are many highly salacious animals—as the kangaroo, and the monkey—which are not distinguished for unusual size of cerebellum. A strong argument, as before observed, in favour of this function of the cerebellum, is founded on the assertion, over and over again repeated, that in animals that have been castrated young, it is much smaller than in the entire male; but the results of the experiments of M. Lassaigne, suggested by M. Leuret,[3] are directly opposed to this. These were made on ten stallions, of the ages of from nine to seventeen years; on twelve mares, aged from seven to sixteen years; and on twenty-one geldings, aged from seven to seventeen years. The weight of the cerebrum, estimating the cerebellum as 1, was thus expressed.

	Average.	Highest.	Lowest.
Stallions	7·07	7·46	6·25
Mares	6·59	7·00	5·09
Geldings	5·97	7·44	5·16

The average proportional size of the cerebellum in geldings was therefore positively greater than in entire horses and mares. It was also found to be absolutely heavier in the following proportions.

	Average.	Highest.	Lowest.
Stallions	61	65	56
Mares	61	66	58
Geldings	70	76	64

It would seem, that the dimensions of the cerebrum are usually reduced by castration; as in the following table.

	Average.	Greatest.	Least.
Stallions	433	485	350
Mares	402	432	336
Geldings	419	566	346

[1] Müller's Elements of Physiology, by Baly, p. 833, Lond., 1838.
[2] Medical Examiner, August, 1852, p. 497.
[3] Anat. Compar. du Système Nerveux, tom. i. p. 427.

These observations are certainly entirely opposed to the statements of the phrenologists; and are more favourable to the idea of the cerebellum being connected with muscular power. Geldings, as is well known, are employed in active labour; whilst stallions are rarely called upon to exert much effort, being kept especially to propagate their kind. It has been maintained by some physiologists, as by M. Serres, that whilst the hemispheres of the cerebellum are concerned in motion, the central lobe is connected with the instinct of reproduction. Dr. N. S. Davis[1] has, however, shown from positive observation, that no difference can be perceived in the size of either the cerebellar hemispheres or the central lobes in bulls and oxen.

It will be obvious, moreover, that if a single case of absence of the cerebellum should be observed in which erotic desires exist; it would be fatal to all these views of the phrenologist. Such cases are rare, but one has been witnessed and recorded by M. Combette,[2] and no doubt can exist as to its authenticity. On examining the encephalon of a young girl, who had been addicted to masturbation, a gelatiniform membrane of a semicircular shape, united to the medulla oblongata by two membranous and gelatinous peduncles, was observed in place of the cerebellum. The one on the right side had been torn. Near these peduncles, M. Combette found two small masses of white substance, isolated and detached, as it were, of the size of a pea. It is not, therefore, a matter of astonishment, that from an examination of all the evidence adduced on this matter, M. Longet[3] should have concluded, that neither pathology, morbid anatomy, comparative anatomy nor experimental physiology leads to the admission of the views of the phrenologist in regard to the functions of the cerebellum.

It is, moreover, affirmed by Dr. Carpenter[4] on the strength of decided assertions of Professor Retzius, of Stockholm, who has paid especial attention to this subject, that the size of the cerebellum in the different races of man bears no relation whatever to the degree of projection of the occiput; so that even were it admitted that the cerebellum is the seat of the instinct of reproduction, no examination of the skull could possibly indicate its size.

In regard, too, to the cerebral seat of the love of progeny—philoprogenitiveness, as it is termed—it is a fatal objection, that, although the instinct is strongly developed in the lower animals, the posterior lobes recede as we descend in the scale from man, and ultimately leave the cerebellum uncovered.

One of the greatest objections brought against the system of Gall is the independence of the different faculties of each other. Each is made to form a separate and independent state, with no federative jurisdiction to produce harmony in their actions, or to regulate the numerous independent movements and complicated associations, which must in-

[1] Transactions of the Amer. Med. Assoc., iii. 415.

[2] Revue Médicale, ii. 57, Paris, 1831; Cruveilhier, Anat. Pathol., livr. xv. pl. v.; Longet, Anat. et Physiol. du Système Nerveux, i. 755, Paris, 1842; and Traité de Physiologie, ii. 270, Paris, 1850.

[3] Op. cit., p. 272.

[4] Principles of Human Physiology, Amer. edit., by Dr. F. G. Smith, p. 518, Philad., 1855.

evitably occur in the various intellectual and moral operations. Gall appears indeed to have lost sight of the important doctrine of association, which applies not only to the ideas, but to every function of the frame; and with which it is so important for the pathologist particularly to be acquainted.

The second point of doctrine,—that each of the cerebral organs ends at the periphery of the encephalon, and is indicated by more or less developement of the part,—is attended with equal difficulties. It is admitted, as we have seen, by the most eminent physiologists, that the exterior of the brain is probably chiefly concerned in the mental and moral manifestations. Almost all believe, that this function is restricted to the brain proper. Gall and his followers include the cerebellum. Yet we meet with cases, which appear to militate strongly against this notion. Hernia of the brain is one: in this affection, owing to a wound of the cranium and dura mater, a portion of the cerebral substance may protrude and be removed; yet the individual may, to all appearance, retain his faculties unimpaired. This is explained by the craniologist, by presuming, that as the fibres of the brain are vertical, their extremities alone have been removed, a sufficient amount of fibres remaining for the execution of the function; and he farther entrenches himself in the difficulty of observing accurately, whether the faculties be really in their pristine integrity. He asserts, that it is frequently difficult to prove the existence of mental aberration; that the precise line of demarcation between reason and unsoundness of mind is not easily fixed; and that commonly, in these cases, attention is paid only to the most general qualities; and if the patient be seen to take food and medicine when offered, to reply to questions put to him, and to have consciousness, the moral sense is esteemed to be free, and in a state of integrity. It must, however, be admitted, that the explanation of the craniologist on these topics is feeble and unsatisfactory. It is gratuitously assuming, that observation in such cases has been insufficient; and if he finds, that the fact in question militates against the faith he has embraced, he is too apt to deny its authenticity altogether. With all the candour which Gall possessed, this failing is too perceptible in his writings.

In many of the cases of severe injury of the brain on record, but one hemisphere was implicated; and, accordingly, the impunity of the intellectual and moral manifestations has been ascribed to the cerebrum being a double organ; so that, although one hemisphere may have been injured, the other, containing similar organs, may be capable of carrying on the function; as one eye can still execute vision, when the other is diseased or lost. Cases, however, have occurred in which the faculty was lost, when only one hemisphere was implicated. An interesting example, the author heard Mr. Combe relate. A gentleman suddenly forgot all words but *yes* and *no;* and after death a lesion was found in the left hemisphere of the brain, involving the phrenological organ of language. The explanation by Mr. Combe of this phenomenon is plausible, but not probable. It appears to me, he observed, "that the lesion's being on one side only accounts for his power of understanding words, while he had not the power of employing them."[1]

[1] Combe's Lectures, by Boardman, p. 261, New York.

Many cases, again, are recorded, in which injury was sustained by both hemispheres, and in corresponding parts, yet the faculties persisted;[1] whence Müller has concluded, that the histories of injuries of the head are directly opposed to the existence of special regions of the brain, destined for special mental faculties. An interesting case of this nature was reported to the Royal Academy of Sciences of Paris, by M. Blaquière of Mexico.[2] A child, playing with a loaded pistol, discharged it accidentally. The ball struck his younger brother, four years and a half old; entered at one temporal region, and came out at the other. For twenty-six days after the accident, the child apparently possessed all its intellectual faculties. Memory and judgment did not seem to be in the slightest degree impaired; the boy was as gay as usual; had appetite, and slept pretty well. The wounds were both situate about an inch and a half below the external commissures of the eyes. On the 26th day, symptoms of cerebral inflammation supervened, and the boy died on the 29th. On examination after death, the anterior and superior regions of both hemispheres were found to have been traversed by the ball. The ventricles were untouched. Throughout the whole track of the ball suppuration existed. The meninges were inflamed. M. Blaquière considers the case to be fatal to phrenological doctrines, as the seats of several important phrenological faculties were destroyed, and yet no functional affection of the brain was discovered. Cases of hydrocephalic patients are likewise cited, who have preserved their faculties entire. These Gall[3] explains, by affirming, that the brain is not dissolved in the fluid of the dropsy; that it is only deployed, and distended by the presence of the fluid; and as the distension takes place slowly, and the pressure is moderate, the organ may be so habituated to it as to be able to continue its functions. Lastly, some experiments of Duverney[4] have been adduced as objections to the views of Gall. These consisted in removing the whole of the brains of pigeons; yet no change seemed to be produced in their faculties; but, in reply to this, it is asserted, that Duverney could only have removed some of the superficial parts of the organ; for, whenever the experiment has been repeated so as to implicate the deeper-seated portions, opposite results have been obtained.

The truth is, that under any view of the subject these facts are equally mysterious. We cannot understand why, in particular cases,

[1] For many such, see Longet, Anatomie et Physiologie du Système Nerveux, i. 670, Paris, 1842; and a remarkable case by Mr. Ford, and another by Dr. Cowan, copied into the Amer. Journ. of the Med. Sciences, Jan., 1846. See, also, a fatal case of disorganization of the brain, without corresponding derangement of the intellectual and moral acts, by Dr. G. W. Boerstler, of Lancaster, Ohio, in Dunglison's American Medical Intelligencer, No. 1, for April 1, 1837. Mr. Combe, in his work,—"*Notes on the United States of North America, during a phrenological visit in* 1838–39–40;" Phila., 1841—refers to a case of injury of both hemispheres, which, he thinks, from examining the case, was confined almost entirely to the organs of Eventuality. The man recovered, and was exhibited to Mr. Combe with a history of his case by Drs. Knight and Hooker, of New Haven. In the opinion of the latter, the intellectual faculties were not impaired.—Vol. ii. p. 276. See, also, connected with this subject, Dr. A. L. Wigan, The Duality of the Mind proved by the Structure, Functions, and Diseases of the Brain, &c., Lond., 1844.

[2] Comptes Rendus, 23ème, Sept., 1844.

[3] Op. citat., ii. 263.

[4] Adelon, Physiologie de l'Homme, 2de édit., i. 502, Paris, 1829.

such serious effects should result from severe injury of the encephalon; and, in others, the comparative immunity attendant upon injury to all appearance equally grave. Pressure, of whatever nature, seems to be more detrimental than any other variety of mechanical mischief; and it is not uncommon for us to observe a total privation of all mental and moral acts, by the sudden effusion of blood, of no greater magnitude than that of a pea, into the substance of the brain; whilst a gun-shot wound, that may occasion the loss of several tea-spoonfuls of brain, or a puncture of the organ by a pointed instrument, may be entirely consistent with the presence of perfect consciousness.

The doctrine, that by observation of the skull we may be able to detect the protuberances produced by the encephalic organs of the different faculties, has, as we have seen, laid the foundation for the whole system of craniology, with all the extensions given to it by absurdity and vain enthusiasm. It has been before remarked, that the size of an organ is but one of the elements of its activity; that by cranioscopy we can of course judge of this element only; and it need scarcely be said, that myriads of observations would be necessary before we could arrive at any accurate specification of the seats of the encephalic faculties, even were we to grant, that separate organs can be detected by the mode of examination proposed by the cranioscopists. Gall asserts, that the whole "physiology of the encephalon is founded on observations, experiments, and researches a thousand and a thousand times repeated on man and animals;" yet the topographical division of the skull proposed by him can hardly be regarded otherwise than premature, to say the least of it;[1] and the remark applies *à fortiori* to that of Spurzheim.

It is, indeed, difficult to grant, that the same convolutions can be the encephalic organs of distinct faculties; and if the views now adopted by many of the phrenologists be admitted, that the number and size of the convolutions and the depth of the anfractuosities be any index of the developement of an organ; it is obviously impossible by an examination of the skull to form the slightest judgment on these points. Messrs. Leuret and Carpenter[2] are of opinion, that comparative anatomy and psychology—which have been so much invoked—when their evidence is fairly weighed, are very far from supporting the system. M. Flourens[3] and Retzius[4] have opposed it on anatomical, physiological, and psychological grounds; and Müller[5] thinks Magendie right in placing cranioscopy in the same category with astrology and alchemy. The author would not go so far; but he must candidly admit, that year after year's observation and reflection render him less and less disposed to consider, that even the fundamental points of the doctrine are founded on a just appreciation of the encephalic functions.

It is the mapping of the skull, accompanied by the self-conceit and

[1] Müller's Elements of Physiology by Baly, p. 837, Lond., 1838.

[2] Human Physiology, p. 226, Lond., 1842. Also, Amer. edit., Philad., 1855.

[3] Journal des Savans, Nov., 1841, & Févr. & Avril, 1842; and Phrenology Examined, translated from the second edition of 1845, by Professor Meigs, Philad., 1846.

[4] Beurtheilung der Phrenologie vom Standpunkte der Anatomie aus., Müller's Archiv., Heft. 3, S. 233, Berlin, 1848.

[5] Op. citat., p. 837.

quackery of many of the *soi-disant* phrenologists or craniologists, that has excited the ridicule of those who are opposed to the doctrine of innate faculties, and to the investigation of points connected with the philosophy of the human mind in any other mode than that to which they have been accustomed. Were we, indeed, to concede, that the fundamental principles of craniology are accurate, we might hesitate in adopting the details; and still more in giving any weight to it as a practical science. Gall and Spurzheim would rarely venture to pronounce on the psychical aptitudes of individuals from an examination of their skulls; and when they did, they frequently failed. "When Gall," says Dr. Burrows,[1] "was in England, he went in company with Dr. H. to visit the studio of the eminent sculptor, Chantry. Mr. C. being at the moment engaged, they amused themselves in viewing the various efforts of his skill. Dr. Gall was requested to say, from the organs exhibited in a certain bust, what was the predominant propensity or faculty of the individual. He pronounced the original must be a great poet. His attention was directed to a second bust. He declared the latter to be that of a great mathematician: the first was the bust of Troughton, and the second that of Sir Walter Scott!"

This kind of hasty judgment from manifestly inadequte data is the every-day practice of the itinerant phrenologist, whose oracular dicta too often draw ridicule not only on the empiric himself, but on a system which is worthy of a better fate. Ridicule is the harmless but attractive weapon, which has usually been wielded against it; and too often by those who have been ignorant both of its principles and details. It is not above twenty years since one of the most illustrious poets of Great Britain included in his satire the stability of the cow-pox, galvanism, and gas, along with that of the metallic tractors of Perkins—

> "The cow-pox, tractors, galvanism, and gas,
> In turns appear to make the vulgar stare
> Till the swoll'n bubble bursts, and all is air."
>
> Byron's "*English Bards and Scotch Reviewers.*"

Yet, how secure in its operation, how unrivalled in its results, has vaccination every where exhibited itself!

Indiscriminate divination from measurement of heads has been a sad detriment to phrenology as a branch of physiological science; and has been grievously deplored by enlightened phrenologists. "Highly as we estimate the discovery of Gall,"—says one of the ablest of these[2]—"immense as we regard the advantages which may be ultimately derived from phrenology, we confess that we wish to see it *less* regarded, studied, and pursued as a separate science, and *more* as a branch of general physiology;" and he adds: "In reviewing the circumstances which have tended to lower phrenology in the estimation of scientific men, and, consequently, to retard both its progress as a science, and the general recognition of its leading truths, we should but very imperfectly perform our task, if we did not refer, in the strongest possible terms of reproof and condemnation, to the too prevalent proceeding of

[1] Commentaries on the Causes, Forms, Symptoms, and Treatment of Insanity, Lond., 1828.

[2] British and Foreign Medical Review, July, 1842.

examining living heads in minute detail and indiscriminately, and supplying the owners with an account of the 'developement,' often on the receipt of a fee, varying in amount, as there is furnished or omitted a general deduction as to the character and probable conduct of the individual, with or without the 'philosophy,' according to the phraseology of practitioners of this art. We unhesitatingly maintain, that the science is not sufficiently advanced to supply evidence of its truth from every head, or from any one head, and consequently, that such practice, as a general one, is so much pure charlatanism. Where any strongly marked peculiarity of individual character exists, its outward sign, in appropriate subjects, will certainly be detected; but, from the very nature of the thing, these cases must constitute not the rule, but the exception. The practice we condemn, however, makes no distinction of instances. Injudicious zeal, the common ally of ignorance, a wish for effect, not unfrequently more sordid motives, stimulate the self-styled phrenologist in this empirical career; and, as a matter of course, the errors and mistakes perpetually made are constantly appealed to as indicative of the sandy foundations of the entire phrenological edifice. We write advisedly in this our unqualified reprobation of the popular custom of 'taking developements.' We believe it to be an extension of the practical application of phrenology much beyond its legitimate bounds; and we appeal to any one having acquaintance with its results, whether any thing like uniformity—the true test of accuracy—is obtained in the majority of cases, even when the most experienced and dexterous pronounce their judgment, if their explorations be conducted separately. We ourselves have even witnessed the greatest possible discrepancies. Nay, we have seen the *same* phrenologists furnish one character from the head, and a totally different one from the cast, whilst in ignorance of the original of this latter. This we have known to happen, not merely in the practice of one of your shilling-a-head itinerants, but in that of one not unknown to fame in the annals of the science." Such are the views of one, who, unlike the author, expects much from phrenology; and has done much to give it countenance. Yet men will still form their judgments in this manner; and a solitary coincidence, as in all analogous cases, will outweigh a dozen failures.[1]

The doctrine of separate cerebral organs, of the phrenologists, has been for some time in a state of decadency, and has recently lost an able supporter in Dr. Noble, whose work on the "Brain and its Physiology" has been, even recently, referred to as one of "the best for the medical student who desires to read the arguments in favour of the system."[2] Dr. Noble,[3] convinced of the inadequacy of the evidence in its favour, has, in a frank and manly manner, published his recantation, and "influenced by the present advanced state of our knowledge of the brain and nervous system in man, and still more by certain facts in comparative anatomy, has been led to the conclusion that it should at

[1] See, on these subjects, the author's Medical Student, second edit., p. 256, Philadelphia, 1844.

[2] Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 340 (note), Philadelphia, 1853.

[3] Elements of Psychological Medicine, p. 45, London, 1853.

least be rejected as *unproved;*" and consequently that he cannot now profess himself to be an adherent "of what is commonly understood by the phrenological *system*." "Altogether"—he adds—"I feel myself bound to say the organology of Gall's doctrine must be abandoned. Honesty and candour compel me to this admission, though with some reluctance, for it involves the recantation of opinions for many years entertained and avowed."—"I will add a few words concerning the premature success of the phrenological system, and upon the fact of its unmistakable decline in the estimation of our profession. The eminently scientific character of many of Gall's researches into the anatomy and physiology of the brain and nervous system, the decidedly philosophic spirit displayed in the tone of much that he wrote, and the important additions, which he undoubtedly made to the then current knowledge of the subject of his investigation, were all circumstances accrediting him to the profession as a faithful observer and accurate interpreter of nature. Then, there were the ingenuity and the lucidity of Spurzheim's speculations, and the comprehensive reasonings of Dr. Andrew Combe and Mr. George Combe. There was, moreover, a boldness and an earnestness in their arguments, claiming for the phrenological system an extensive applicability in so many practical relations of life,—arguments which, containing much truth, it would have been very often difficult, without great labour, to confute. All these things constituted obvious reasons why many, in the first instance, accepted phrenology so largely upon trust. When I have had the opportunity of conversing with undoubtedly able men, especially of the medical profession, who avowed their conviction of the truth of phrenology, I have always noticed, that whilst uneducated charlatans recognize no difficulties either in judging of character, or in estimating cerebral developement, they, on the contrary, have constantly spoken with distrust of their ability to decide in these respects; showing plainly enough, that their adhesion resulted from the confidence which they have placed in the more prominent apostles and disciples of the system, rather than from any accurate or careful investigations made by themselves. In my own instance, many circumstances have utterly destroyed my confidence in the observations and the judgment of large numbers of the phrenologists: amongst others, I may adduce the striking fact that the ranks of almost every philosophical folly of the present era, so distinguished in this point of view, have been largely recruited from the expiring phrenological school-teachers and disciples alike. Some have become apostles or partisans of the water-cure; others of clairvoyance and mesmeric prevision; and some, again, of homœopathy; whilst a few, I believe, have gone over to the spiritual rappers! With the same men, there continues the same turn of mind,—the excessive credulity, the readiness to see whatever is looked for, and to wink at, or most elaborately to explain away every thing which makes against the adopted faith; the same bigotry, too, and the same restless spirit of propagandism." "If"—he concludes—"I have dwelt upon this subject at somewhat undue length, it is because I have been anxious to give reasons for the decline of phrenology, both in my own estimation, and in that of others of our profession, who formerly anticipated other results."

The doctrine of Gall—which, in its details, has never met with favour from the author—requires repeated unbiassed and careful experiments, which it is not easy for every one to institute; and this is one of the causes why the minds of individuals must long remain in doubt regarding the merits or demerits of the system. From mere metaphysicians, who have not attended to the organization and functions of the frame, especially of its encephalic portion, it has ever experienced the greatest hostility; although their conflicting views regarding the intellectual and moral faculties was one of the grounds for the divisions of the phrenologist. It is now, however, we believe, generally admitted by the liberal and scientific, that if we are to obtain a farther knowledge of the mental condition of man, it must be by a combination of sound psychological and physiological observation and deduction. It is time, indeed, that such a union should be effected, and that the undisguised and inveterate hostility, which exists between certain of the professors of these interesting departments of anthropology, should be abolished. "To fulfil, definitely, the object we had proposed to ourselves," says M. Broussais,"[1] "we must infer from all the facts and reasoning comprised in this work,—1st. That the explanations of psychologists are romances, which teach us nothing new. 2dly. That they have no means of affording the explanations they promise. 3dly. That they are the dupes of the words they employ in disserting on incomprehensible things. 4thly. That the physiologist alone can speak authoritatively on the origin of our ideas and knowledge; and 5thly. That men, who are strangers to the science of animal organization, should confine themselves to the study of the instinctive and intellectual phenomena in their relations with the different social states of existence."

This is neither the language nor the spirit that ought to prevail among the promoters of knowledge.

Lastly.—Physiologists have inquired, whether there may not be some particular portion of the brain, which holds the rest in subservience; some part in which the mind exclusively resides;—for such was probably the meaning of the researches of the older physiologists into the seat of the soul. It is certain, that it is in the encephalon, but not in the whole of it; for the organ may be sliced away, to a certain extent, with impunity. Gall, we have seen, does not admit any central part, which holds the others in subordination. He thinks, that each encephalic organ, in turn, directs the action of the others, according as it is, at the time, in a state of greater excitation. On the other hand, different physiologists admit of a central cerebral part, which they assert to be the seat of the ψυχη, *moi* or mind. They differ however, regarding the precise situation of its domicile. At one time, the strange notion prevailed, that the seat of perception is not in the brain, but in its investing membranes. Des Cartes,[2] again, embraced the singular hypothesis, that the pineal gland is entitled to this pre-eminence. This gland is a small projection, seen in Fig. 189 (vol. i. p. 633),

[1] De l'Irritation et de la Folie, Paris, 1828; or Amer. edit. by Dr. T. Cooper, Columbia, S. C., 1831.

[2] De Passion. Anim., Amst., 1664, and De Homine, p. 78, Lugd. Bat., 1664.

at the posterior part of the third ventricle; and, consequently, at the base of the brain. Being securely lodged, it was conjectured by that philosopher, that it must be inservient to some important purpose; and, upon little better grounds, he supposed that the soul is resident there. The conjecture was considered to be confirmed by the circumstance, that, on examining the encephala of certain idiots, the gland was found to contain a quantity of sabulous matter. This was supposed to be an extraneous substance, which, owing to accident or disease, had lodged in the gland and impeded its functions; and the inference was drawn, that the part, in which such functions were impeded, was the seat of the soul. Nothing, however, is now better established than that the pineal gland of the adult always contains earthy matter.[1] Others, again, as Bontekoe,[2] La Peyronie,[3] and Louis, placed the mind in the corpus callosum; Vieussens in the centrum ovale; Digby[4] in the septum lucidum; Drelincourt[5] in the cerebellum; Ackermann in the Sinneshügel[6] (prominence or tubercle of the senses); Sömmering[7] in the fluid of the ventricles; and the greater part of physiologists in the point where the sensations are received and volition sets out,—the two functions, which, together, form the *sensorial power* of Dr. Wilson Philip.[8] Dr. Darwin[9] had previously employed this term in a more extended sense, as including the power of muscular contraction: but in Dr. Philip's acceptation it is restricted to those physiological changes in which the mind is immediately concerned.[10]

The discrepancy among physiologists sufficiently demonstrates, that we have no positive knowledge on the subject.

CHAPTER II.

MUSCULAR MOTION, ESPECIALLY LOCOMOTILITY OR VOLUNTARY MOTION.

THE functions hitherto considered are preliminary to those that have now to attract attention. The former instruct us regarding the bodies that surround us; the latter enable us to act upon them; to execute all the partial movements, that are necessary for nutrition and reproduction; and to move about from place to place. All these last acts are of

[1] Sömmering, De Lapillis vel prope vel intra Glandulam Pinealem sitis, Mogunt. 1785.
[2] Haller. Bibl. Anat., i. 673.
[3] Mém. de l'Académ. des Sciences, Paris, 1741.
[4] Of the Nature of Bodies and the Nature of Man's Soul, London, 1658.
[5] Opera. Anat., Lugd. Bat., 1684.
[6] This term he applies to the optic thalami and corpora striata; because, according to the then received opinion, the optic nerves originate in the optic thalami, and the olfactory nerves from the corpora striata. Gall, Sur les Fonctions du Cerveau, ii. 57, Paris, 1825.
[7] De Corp. Human. Fabric., iv. § 98.
[8] An Experimental Inquiry into the Laws of the Vital Functions, p. 186, London, 1817.
[9] Zoonomia, 3d edit., ii. 103, Lond., 1801.
[10] Dr. W. Philip, ibid.; and especially his paper on the Powers of Life, in the Lond. Med. Gazette for March 18 and 25, 1837; and his Treatise on Protracted Indigestion, &c., Amer. edit., Philad., 1843. See, also, on this subject, Ludwig, Lehrbuch der Physiologie des Menschen, 1er Band, S. 452, Heidelberg, 1853.

the same character; they are varieties of muscular contraction; so that sensibility, and voluntary motion or muscular contraction executed by the muscular system of animal life, comprise the whole of the life of relation. M. Magendie includes the voice and movements under the same head; but there is convenience in separating them; and in treating the functions of locomotility and expression distinctly, as has been done by M. Adelon.[1]

1. ANATOMY OF THE MOTORY APPARATUS.

The organs essentially concerned in this function are—the encephalon, spinal marrow, nerves, and muscles. The first three of these have been sufficiently described. The last, therefore, will alone engage us.

a. *Muscles.*

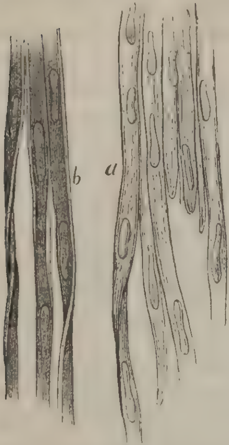
The muscles constitute the flesh of animals. They are distinguished by their peculiar structure and composition;—being formed of the elementary or primary fibrous tissue, already described. This tissue has the power of contracting, and thus of moving the parts into which it is inserted; hence, muscles have been termed *active* organs of locomotion, in contradistinction to bones, tendons, and ligaments, which are *passive*.

The elementary constituent of the whole muscular system is this primary, fibrous, or muscular tissue, the precise size and intimate texture of which have been the occasion of innumerable researches; and, as most of them have been of a microscopic character, they are highly discrepant, as a brief history will exhibit.

Leeuwenhoek[2] asserts, that some thousands of the ultimate filaments are required to form the smallest fibre visible to the naked eye. He describes these fibres as serpentine and cylindrical; and affirms, that they lie parallel to each other, and are of the same shape in all animals, but differ greatly in size. Their size, however, bears no proportion to that of the animal to which they belong. Muys[3] affirmed, that every apparent fibre is composed of three kinds of fibrils, each progressively smaller than the other; and that those of the medium size, although not larger than the ninth part of a very delicate hair, are composed of one hundred filaments. He supposed the ultimate filament to be always of the same size. Prochaska[4] says, that the ultimate fibre or filament is discernible, and that its thickness is about the $\frac{1}{50}$th part of the diameter of the red globules of the blood; and MM. Prévost and Dumas,[5] from the result of their microscopic observations, affirm that 16,000 fibres may be contained in a cylindrical nerve, one millimeter or 0·039 of an inch in diameter. The microscopic examinations of Mr. Skey,[6] which have been confirmed and developed by subsequent observers, led him to infer, that there is a distinction between the muscular fibres of

[1] Physiologie de l'Homme, 2de édit., ii. 1 and 204, Paris, 1829.
[2] Arcana Naturæ, p. 43.
[3] Investigatio Fabricæ quæ in Partibus Musculos Componentibus exstat, p. 274, Lugd. Bat., 1841.
[4] De Carne Musculari, p. 25, Vienn., 1778.
[5] Annales de Chimie, tom. xviii.; Magendie's Journal de Physiologie, tom. iii.
[6] Transactions of the Royal Society, for 1836.

Fig. 332.



Non-striated Muscular Fibre.

At *b*, in its natural state. At *a*, showing the nuclei after the action of acetic acid.

animal and of organic life; the former having, in man, an average diameter of $\frac{1}{400}$th of an inch. Each of these muscular fibres is divisible into bands or fibrillæ, and each of these is again subdivisible into about 100 tubular filaments, arranged parallel to each other: the diameter of each filament is $\frac{1}{10000}$th part of an inch, or about a third part of that of a blood-globule. The muscles of organic life he found to be composed, not of fibres similar to those described, but of filaments only; these filaments being interwoven, and forming a kind of untraceable network. The fibres of the heart appeared to possess a somewhat compound character of texture: the muscles of the pharynx exhibited the character of those of animal life, whilst those of the œsophagus, stomach, intestines, and arterial system possessed the character of those of organic life. He was unable to determine the exact nature of the muscular fibres of the iris. At the present day, muscular tissue is universally divided into two kinds;—the one forming the *muscles of animal life*, and the other the *muscles of organic life*. The former, called also *striated* and *striped muscles* (see Fig. 335), embrace all the voluntary muscles, as well as the heart, the muscular tissue of the pharynx and upper portion of the œsophagus: the latter, called also *non-striated* or *unstriped muscles*, constitute the proper contractile coats of the digestive tube from the middle of the œsophagus to the external sphincter ani, as well as those of the urinary bladder, trachea and bronchia, excretory ducts, gall bladder, vesiculæ seminales, pregnant uterus and Fallopian tubes; arteries, and—to a less degree—of the veins.

Fig. 333.

Non-striated Muscular Fibre.

4. Muscular fibre of organic life, with two of its nuclei; taken from the urinary bladder, and magnified 600 diameters. 5. Muscular fibre of organic life from the stomach, magnified the same.

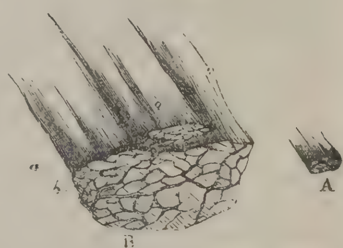
The intimate structure of the filaments has given rise to extraordinary contrariety of sentiment;—some, as Santorini, Heister, Cowper,[1] Vieussens, Mascagni,[2] Prochaska,[3] Borelli,[4] John Bernouilli, &c., believing them to be hollow; others, as Sir A. Carlisle,[5] and Fontana,[6] solid; some thinking them straight; others zigzag, spiral, or waved; some jointed; others knotted, &c. &c.[7] Borelli and J. Bernouilli announced, that each fibre consists of a series of hollow vesicles, filled with a kind of spongy substance or marrow;—the shape of the vesicles

[1] Myotomia Reformata, Lond., 1724.
[2] Prodromo, p. 97.
[3] Oper. Minor., pt. i. p. 98.
[4] De Motu Animalium; addit. Johan. Bernouilli, M. D., Meditationes Mathematic. Musculorum, Lugd. Bat., 1710.
[5] Phil. Trans. for 1805, p. 6.
[6] Sur les Poisons, ii. 228.
[7] Elliotson's Physiology, p. 476.

being, according to the former, rhomboidal,—according to the latter, spheroidal. Deidier conceived it to be a fasciculus, composed of an artery, vein, and lymphatic, enveloped by a nervous membrane, and held together by nervous filaments:—Prochaska, to consist of bloodvessels turned spirally around an axis of gelatinous or fibrinous substance, into the interior of which the blood rushes at the time of contraction. He says, that the visible fibres are not cylindrical, as they had been described by many observers, but of a polyhedral shape; and that they are generally flattened, or thicker in one direction than in the other. All are not of the same diameter: they differ in different animals, and in different parts of the same animal; and are smaller in young subjects. The filaments or ultimate fibres, which can only be seen with the microscope, have the same shape as the visible fibres: they are, however, always of the same magnitude. Sir A. Carlisle,[1]—whose opinions, on many subjects at least, are not entitled to much weight,—describes the ultimate fibre as a solid cylinder, the covering of which is a reticular membrane, and the contained part a pulpy substance, regularly granulated, and of very little cohesive power when dead. The extreme branches of the bloodvessels and nerves, he says, are seen ramifying on the surface of the membrane enclosing the pulp, but cannot be traced into the substance of the fibre. Mr. Bauer[2] and MM. Prévost and Dumas[3] differed essentially from the observers already mentioned. Mr. Bauer found, that the muscular fibre was composed of a series of globules, arranged in straight lines; the size of the globule being $\frac{1}{2000}$th part of an inch in diameter; whilst M. Raspail[4] considers, that the intimate structure of the muscular tissue, when it is in its most simple state, consists of a bundle of cylinders, intimately agglutinated together, and disposed, in a very loose spiral form, around the ideal axis of the group. These tubes are filled with a substance not wholly miscible with water, and may be regarded as elongated vesicles, united at each end to other vesicles of a similar character.

When a muscular fibre is seen through an ordinary microscope, it appears to be composed of longitudinal filaments, each consisting of a string of globules, about $\frac{1}{8000}$th of an inch in diameter. "But with a better instrument," says Mr. Mayo,[5] "such as that which Mr. Lister possesses, the delusion vanishes, and the parallel lines, which traverse the fibre, appear perfectly clean and even. Mr. Lister politely gave me an opportunity of examining this appearance, which was discovered by himself and Dr. Hodgkin."

Fig. 334.



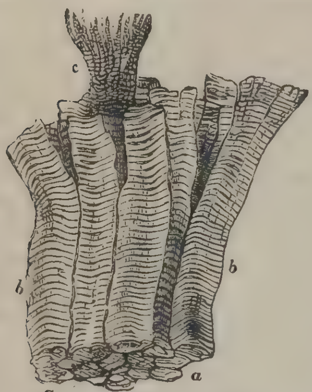
Striated Muscular Fibres.

A. A small portion of muscle, natural size. B. The same magnified 5 diameters, of larger and smaller fasciculi, seen in a transverse section.

[1] Op. citat.
[2] Sir E. Home, Lectures on Comp. Anat., v. 240, Lond., 1828.
[3] Appendix to Edwards, De l'Influence des Agens Physiques sur la Vie, Paris, 1824.
[4] Chimie Organique, &c., p. 211, Paris, 1833.
[5] Outlines of Human Physiology, chap. iii. 3d edit., London, 1833.

The researches of Mr. Bowman[1] and others are as follows. When the smallest fibre, that can be seen by the naked eye, is examined by the microscope, it is found to consist of a number of cylindrical fibres lying parallel to each other, and closely bound together. These fibres present striæ—one set of which is longitudinal, the other transverse. When the fibres are separated from each other, and examined more closely, they may be resolved into fibrillæ, which, so far as at present known, are the ultimate elements of muscular structure. They are represented in Figure 341. The fibrillæ are bound together by a delicate tubular sheath or *sarcolemma*, which may be distinctly seen, when the two ends of a fibre are drawn apart. The contained fibrillæ will rupture, whilst the sheath remains entire, as represented in Fig. 336. During the act of contraction, it is also sometimes observed to rise up in wrinkles, upon the surface of the fibre, as in Fig. 353. It is distinct from the cellular tissue that binds the fibres into fasciculi; does not appear to be perforated by nerves or capillary vessels; and evidently has no share in the contraction of the fibre. Although commonly described as cylindrical, these fibres would seem to be rather of a polygonal form, their sides being flattened against those of the adjoining fibres. Their size varies greatly in different classes of animals, and even in the same animal, and the same muscle. Mr. Bowman found them to be, in the human male, from $\frac{1}{507}$ to $\frac{1}{192}$ of an inch; in the female, from $\frac{1}{605}$ to $\frac{1}{384}$, and it has been estimated, that each fibre may be composed of from 500 to 800 fibrillæ. Illustration, Fig. 337, representing a transverse section of the fibres from the pectoral muscle of a teal; and Fig. 338, a transverse section of the ultimate fibres of the biceps, exhibit well the irregular shape and size, and the cut extremities of fibrils that go to the constitution of the fibre. Under the microscope each fibre exhibits a close alternation of light and dark lines crossing it transversely, which are presumed to be owing to the arrangement of beaded fibrillæ, as shown in Fig. 339. The beaded enlargements of the fibrillæ seem to adhere

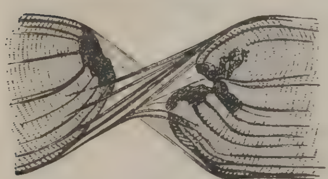
Fig. 335.



Striated Muscular Fibres.

A few muscular fibres, being part of a small fasciculus, highly magnified, showing the transverse striæ. *a.* End view of *b b*, fibres; *c.* A fibre split into its fibrillæ.

Fig. 336.

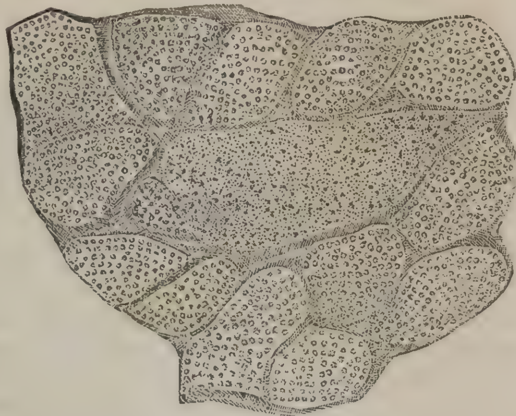


Fragments of an Elementary Fibre of the Skate, held together by the untorn but twisted Sarcolemma.

[1] Philosophical Transactions for 1840; art. Muscle, Cyclop. of Anat. and Physiol., Part xxiv., p. 507, July, 1842; and Todd and Bowman's Physiological Anatomy and Physiology of Man, Part i., Lond., 1843.

closely to each other, so that when the extremities of a fibre are drawn apart, it not unfrequently happens, that the disks formed by them separate.

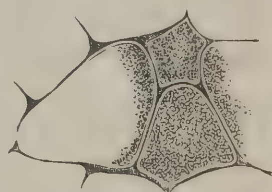
Fig. 337.



Transverse Section of Fibres from the Pectoral Muscle of a Teal.

It has been affirmed, that the primitive component segments of the fibrillæ are the ultimate elements of the fibre; these segments being connected longitudinally, so as to constitute the fibrillæ, the distinctness of which is marked, even in the complete fibre, by longitudinal striæ; whilst they also adhere laterally, so as to form disks, the partial separation of which gives origin to the transverse striæ.

Fig. 338.



Transverse Section of Ultimate Fibres of Biceps.

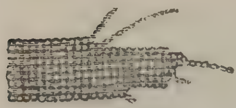
The views of histologists on the whole of this subject have until of late years been sufficiently discrepant. Dr. Martin Barry[1] revived a view of Döllinger, but which has met with little favour, and certainly needs demonstration, that the blood corpuscle is the immediate agent in the construction of many tissues, particularly the muscular, the elementary fibre of which—called by him *spiral fibre*—may even be detected in the nucleus of the corpuscle. Mr. Bowman[2] has affirmed, that the muscular fibre always presents, upon and within it, longitudinal dark lines, along which it will generally split up into fibrillæ, but it is by a fracture alone, that the fibrillæ are obtained. They do not exist as such in the fibre. He farther observed, that it occasionally happens that no disposition whatever is shown to this longitudinal *cleavage;* but that, on the contrary, violence causes a separation along the transverse dark lines, which always intersect the fibre in a plane perpendicular to its axis. By such a cleavage, disks and not fibrillæ are obtained; and this cleavage is as material as, although less frequent than, the former. Hence, he esteems it as proper to say, that the fibre is a pile of disks, as that it is a bundle of fibrillæ; that it is, in fact, neither one nor the other; but a mass in the structure of which

[1] Philosophical Transactions, for 1842, Part i. p. 89.

[2] Art. Muscle, Cyclopædia of Anat. and Physiology, July, 1842, p. 508, and Physiological Anatomy and Physiology of Man, Part i., Lond., 1843.

there is an intimation of the existence of both, and a tendency to cleave in the two directions. If there were a general disintegration

Fig. 339.



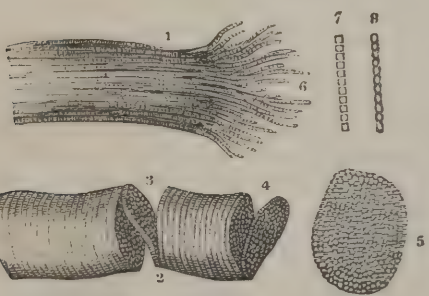
Fragment of Muscular Fibre from macerated heart of Ox, showing formation of striæ by aggregation of beaded fibrillæ.

Fig. 340.

Portion of Human Muscular Fibre, separating into disks, by cleavage in direction of transverse striæ.

along all the lines in both directions, there would result a series of particles, which might be termed *primitive particles* or *sarcous elements*, the union of which would constitute the mass of the fibre; these elementary particles being arranged and united together in the two directions.

Fig. 341.



Fragments of Striated Elementary Fibres, showing a Cleavage in Opposite Directions.—Magnified 300 diameters.

1. Longitudinal cleavage. The longitudinal and transverse lines both seen. Some longitudinal lines darker and wider than the rest, and not continuous from end to end: this results from partial separation of the fibrillæ. 6. Fibrillæ, separated from one another by violence at the broken end of the fibre, and marked by transverse lines equal in width to those on the fibre. 7, 8 represent two appearances commonly presented by the separated single fibrillæ. (More highly magnified.) At 7, the borders and transverse lines are all perfectly rectilinear, and the included spaces perfectly rectangular. At 8, the borders are scalloped, the spaces bead-like. When most distinct and definite, the fibrilla presents the former of these appearances.—2. Transverse cleavage. The longitudinal lines are scarcely visible. 3. Incomplete fracture following the opposite surfaces of a disk, which stretches across the interval and retains the two fragments in connexion. The edge and surface of this disk are seen to be minutely granular, the granules corresponding in size to the thickness of the disk, and to the distance between the faint longitudinal lines. 4. Another disk nearly detached. 5. Detached disk more highly magnified, showing the sarcous elements.

Gerber[1] is disposed to consider, that the "cross-streaking" frequently depends on the presence of a wrinkled fascicular sheath; "for when," he says, "the more superficial fibres chance to be removed, and the deeper ones exposed, these appear cylindrical, and the bundle at the part is longitudinally streaked. At the extremity of a torn fasciculus, too, the peripheral fibres often appear so distinctly marked off from the internal and more pulpy substance, that the existence of a more compact transversely streaked sheath can scarcely be called in question." Dr. Goddard[2] is of opinion, from his own observations, that the transverse striæ seem to be produced by a delicate thread of areolar tissue

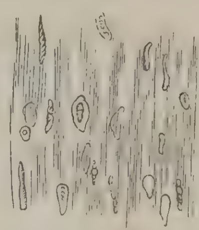
[1] Elements of General and Minute Anatomy, by Gulliver, p. 251.

[2] Wilson's Anatomist's Vade Mecum, by Goddard, Amer. edit., p. 142, Philad., 1843.

wound spirally around the ultimate fibrils, so as to hold them in a bundle; whilst Dr. Will[1] thinks that they are owing to the fibrils, which, in their natural relaxed state, are uniform and cylindrical, being thrown in contraction into undulations or zigzag flexures; and Valentin,[2] who has long described the relaxed muscular fibre as a uniform cylinder, confirms, generally, Dr. Will's account, although he cannot determine, whether the striated appearance of the fibrils be owing to their becoming varicose, or to zigzag flexures induced by contraction. He also maintains the view, long professed by him, that the fibres and fasciculi in the fully contracted state, are bent in zigzag lines, with angles of from 80° to 120°. The zigzag arrangement of fibres having the appearance of "series of rhomboidal pinnulæ, which immediately disappear as soon as the muscle ceases to act," was observed by Hales,[3] in the abdominal muscles of the frog.

Mr. Erasmus Wilson,[4] by resorting to peculiar methods of manipulation, and employing a microscope of more than ordinary power, believes that he has succeeded in discovering the real structure of the ultimate muscular fibril in a specimen taken from the arm of a strong healthy man immediately after amputation. He finds each fibril to be composed of minute cells disposed in a linear series, flattened at their surfaces of apposition, and so compressed in the longitudinal direction as to have no marginal indentation on the surface; thus constituting a uniform cylinder divided into minute subdivisions by transverse septa, which are formed by the adherent surfaces of contiguous cells. The diameter of the fibril, in the state of relaxation, is the 20,000th part of an inch. The cells are filled with a transparent substance, to which Mr. Wilson gives the name *myoline*, and which differs in its refractive density in different cells. In four consecutive cells, the myoline is of greater density than in the four succeeding cells, and this alternation is repeated throughout the whole course of the fibril. In consequence of all the fibrils composing the ultimate fasciculus having the same structure; and the cells, which are in lateral juxtaposition, containing myoline of the same density, they act similarly on light, and the whole presents to the eye of the microscopic observer a succession of striæ or bands, dark and luminous alternately, and transverse to the direction of the fasciculus; an appearance which has been noticed by previous observers, but the cause of which, according to Mr. Wilson, had not been before ascertained. A dark stria may occasionally appear as a luminous one, and conversely, when viewed by light transmitted at different degrees of obliquity. The structure here described, Mr. Wilson remarks, reduces the muscular fibre to the simple type of organization exhibited in the combination

Fig. 342.

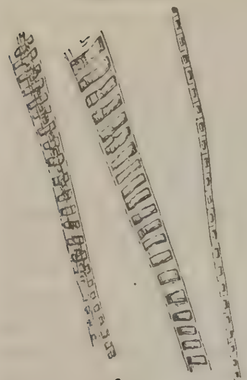


Mass of Ultimate Fibres from the Pectoralis Major of the Human Fœtus, at nine months. These fibres have been immersed in a solution of tartaric acid; and their "numerous corpuscles, turned in various directions, some presenting nucleoli," are shown.

[1] Müller's Archiv., 1843, Heft iv.
[2] Lehrbuch der Physiologie des Menschen, ii. 33, Braunschweig, 1844.
[3] Statical Essays, ii. 61, Lond., 1733.
[4] Proceedings of the Royal Society, June 20, 1844.

of a series of cells, associating it with other tissues of cell formation; and may probably, he thinks, open new sources of explanation of the immediate agency of muscular action,—a power which, as he properly observes, is involved in the deepest mystery.

Fig. 343.



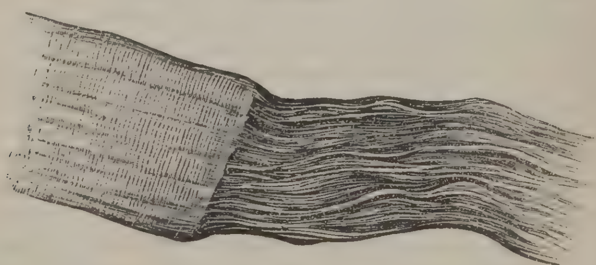
Muscular Fibrils of the Pig.

a. An apparently single fibril.
b. Longitudinal segment of a fibre consisting of a number of fibrils connected together.
c. Other smaller collections of fibrils.—Magnified 720 diameters.

One of the most recent of the views that have been published, is that of Dr. Sharpey[1] and Dr. Carpenter,[2] announced about the same time; according to which, each of the alternate light and dark particles of which the fibril is composed, has a quadrilateral and generally a rectangular form. Each bright particle or space is marked across its centre by a fine, dark, transverse line or shadow, by which the space is divided into two equal parts; and, at times, a bright border is perceptible on either side of the fibril, so that each of the rectangular dark bodies seems to be surrounded by a bright area, having a similar quadrangular outline, as if the pellucid substance inclosed it on all sides;—appearances which have been considered to show, that the elementary particles of which the fibril is composed are little masses of pellucid substance, possibly nucleated cells, presenting a rectangular outline, and appearing dark in the centre.

The ultimate fibres or filaments, when united in bundles, form *fasciculi* or *lacerti;* and these, by their aggregation, constitute the various muscles. Each fibre, each lacertus, and each muscle, is surrounded by a sheath of areolar tissue, which enables them to move readily upon

Fig. 344.



Attachment of Tendon to Muscular Fibre, in Skate.

each other, and preserves them *in situ.* The fibres are not the same at the extremities as they are at the middle. The latter only consist of the proper muscular tissue; the extremities being formed of areolar tissue. If we examine a muscle, we find that the proper muscular fibres become gradually fewer, and at length cease to be perceptible as

[1] Human Anatomy, by Jones Quain, M. D., edited by Quain and Sharpey, Amer. edit., by Leidy, i. 316, Philad., 1849.
[2] Elements of Physiology, Amer. edit., p. 206, Philad., 1846.

they approach the tendon at one or other extremity. In this way, the fibro-areolar membrane, which surrounds every fibre, becomes freed from the muscular tissue; its divisions approximate, and become closely united and condensed, so as to form the *cord* or *tendon*, which, of course, holds a relation to each fibre of the muscle; and when they all contract, the whole force is exerted upon it. The microscopic observations of Mr. Bowman exhibited to him, that the component fibres of the tendinous structure are arranged with great regularity, parallel to each other, and are attached to the end of the sarcolemma, which terminates abruptly, as in Figs. 336 and 344; which shows the attachment of the tendon to the muscular fibre in the skate. Dr. Leidy[1] observed that the filaments of areolar tissue, which form the sheaths of the muscular fasciculi, proceed, for the most part, in a diagonally crossing manner around the fasciculi, occasionally passing in between the fibres and intermingling with fine filaments of elastic tissue which exist in this situation. The sheaths are also connected together by filaments from them, which pursue the same diagonally crossing course. The filaments of the fibro-areolar sheaths become more or less straight at the extremities of the muscular fasciculi, and combine with the fibrous filaments originating there to form the tendinous connexion of the muscle.

The close union that exists between the muscle and its tendon formerly gave occasion to the belief, that the latter is only the former condensed. An examination of some of the physical and vital properties of the two will show, that they differ as essentially as any two of the constituents of the body that could be selected. The tendon consists chiefly of gelatin and albumen, and does not exhibit the same irritability; whilst the muscle is formed essentially of fibrin; and contracts under the will, as well as on the application of certain mechanical and chemical irritants. The differences, in short, that exist between the two, are such as distinguish the primary fibrous and areolar tissues; yet the opinion of their identity prevailed in antiquity; was embraced by Boerhaave and his school, and, as Dr. Bostock[2] observes, was so generally admitted even in the middle of the last century, that Haller[3] and Sabatier[4] scarcely ventured to give a decided opposition to it.

Similar remarks are applicable to the notion of Dr. Cullen,[5] that muscles are only the moving extremities of nerves. The fibres of the muscle were supposed by him to be continuous with those of the nerve; to be, indeed, the same substance, but changed in structure; so that when the nerve is converted into muscle, it loses the power of communicating feeling, and acquires that of producing motion.

Every muscle and every fibre of a muscle is probably supplied with bloodvessels, lymphatics, and nerves. These cannot be traced into the ultimate filament; but, as this must be possessed of life and be con-

[1] Proceedings of the Academy of Natural Sciences of Philadelphia, vol. iv., No. 6, 1848; and Quain's Anatomy, by Quain and Sharpey, Amer. edit., by Leidy, i. 319, Philadelphia, 1849.

[2] An Elementary System of Physiology, 3d edit., p. 84, London, 1836.

[3] Element. Physiol., ii. 1, 18.

[4] Traité complet d'Anatomie, i. 242, Paris, 1791.

[5] Institutions of Medicine, §§ 29, 94; or Works of William Cullen, M. D., by John Thompson, M. D., i. pp. 15, 68, Edinb. and Lond., 1827.

Fig. 345.

Capillary Network of Muscle.

tractile under the will, it must receive through the bloodvessels and nerves the appropriate influences. MM. Dumas and Prévost,[1] and Mr. Bowman,—as has been remarked, — affirm, that the microscope shows, that neither the one nor the other terminates in the muscle. The vessels merely traverse the organs;—the arteries terminating in corresponding veins; so that the nutrition of muscles is effected by the transudation of plastic materials through the parietes of the artery, in the same manner as other parts are nourished. A similar distribution is assigned by them to the nerves. All the branches, they assert, enter the muscle in a direction perpendicular to that of the fibres composing it; and their final ramifications, instead of terminating in the muscular fibres, surround them loopwise, and return to the trunk that furnished them, or anastomose with some neighbouring trunk. In their view, each nervous filament, distributed to a muscle, sets out from the anterior column of the spinal marrow, forming part of a nervous trunk; turns around one or more muscular fibres, and returns along the same or a neighbouring trunk to the posterior column of the marrow.

The red colour of muscles is usually ascribed to the blood distributed to them, as it may be removed by repeated washing and maceration in water or alcohol, without the texture of the muscle being modified. By some, it has been thought, that a quantity of red blood remains attached to the fibres, and is extravasated from the vessel; by others, it is presumed, with more probability, to be contained in the vessels, and according to Mulder,[2] who considers the red colour to be wholly due to the blood in the capillary system of the muscles, when they are injected with water, every muscle is colourless. Bichat[3] conceived, that the colour is dependent upon some foreign substance combined with the fibre; and he grounded his opinion upon the circumstance that, in the same animal, some of the muscles are always much redder than others, and yet they do not appear to have a greater quantity of blood sent to them; and also, that in different classes of animals the colour of the muscles does not appear to correspond with the quantity of red blood circulating through their vessels. The fact, however, that when muscles have been long in a state of inaction they become pale; and that, on the other hand, the colour becomes deeper when they are exercised, is additional evidence, that their colour is dependent upon the blood they receive, which is found to diminish or increase in quantity, according to the degree of inactivity or exertion.

Muscles differ, like the primary fibre, at their extremities and centre; the former being composed of condensed fibro-areolar membrane; the latter of the muscular or fibrous tissue. The centre of a muscle is usually

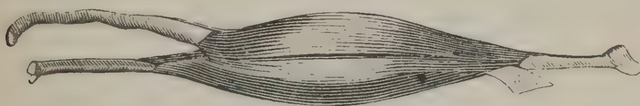
[1] Magendie's Journal de Physiologie, tom. iii.

[2] The Chemistry of Vegetable and Animal Physiology, translated by Fromberg, &c., p. 589, Edinburgh and Lond., 1849.

[3] Anat. Général., ii. 327, Paris, 1818.

called its *venter* or *belly;* and the areolar texture at the extremities is variously termed;—that from which it appears to arise being called the *head* or *origin;* and that into which it is inserted the *tail*, *termination* or *insertion.* These terms are not sufficiently discriminative. We shall find, that a muscle is capable of acting in both directions; so that the head and the tail—the origin and insertion—may reciprocally change places. In ordinary language, however, the extremity at which the *albugineous* tissue (if we adopt Chaussier's nomenclature), assumes a rounded form, so as to constitute a cord or *tendon*, is called the insertion. When this tissue is expanded into a membrane it is termed an *aponeurosis;* and in this state it exists at the head or origin of the muscle; so that by tendon and aponeurosis the muscles are inserted into the parts, which they are destined to move, if we except those that are inserted into the skin.

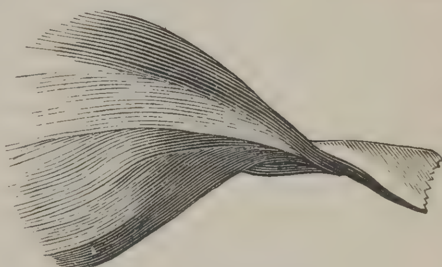
Fig. 346.



Compound Ventriform Muscle.

Muscles are divided into *simple* and *compound.* The *simple* are those whose fibres have a similar course and arrangement. They may be either *flat* or *ventriform*, *radiated* or *penniform.* The *compound* arise from different parts: their origins are, consequently, by distinct fasciculi, or they may terminate by distinct insertions. Fig. 346, which is a representation of the biceps—a flexor muscle of the forearm—is one of these. It has, as its name imports, two heads running into one belly. It is, also, an example of a *ventriform* muscle.

Fig. 347.



Penniform Muscle.

In the pectoralis major, Fig. 347, we have an example of the *radiated* muscle, or of one in which the fibres converge toward their tendinous insertion.

Fig. 348.

Double Penniform Muscle.

In the *penniform* muscle, the fibres run in a parallel direction, but are all inserted obliquely into the tendon, like the feathers of a quill. Fig. 348 is a representation of a *double penniform* muscle. Muscles

may, also, be *complicated:* that is, with one belly, and several tendons having the fibres variously inserted into them; or having several bellies with the tendons interlaced.

They are, again, partitioned into the *long*, *broad*, and *short*. The *long* muscles are situate chiefly on the limbs, and are concerned in locomotion. The *broad* generally form the parietes of cavities: they are not so much enveloped as the long by strong fibrous aponeuroses or fasciæ, owing to their being obviously less liable to displacement; and the *short* are situate in parts, where considerable force is required, and but little motion; so that their fibres are very numerous.

The number of muscles varies, of course, in different animals, in proportion to the extent and variety of motion they are called upon to execute. In man, it is differently estimated by anatomists; some describing several distinct muscles under one name; and others dividing into many what ought to belong to one. According to the arrangement of M. Chaussier, three hundred and sixty-eight distinct muscles are admitted; but others reckon as many as four hundred and fifty.

When muscles are subjected to analysis, they are found to consist of fibrin (*syntonin*); osmazome; jelly; albumen; phosphates of soda, ammonia, and lime; carbonate of lime; chloride of sodium; phosphate, and lactate of soda; and, according to Fourcroy and Vauquelin,[1] sulphur and potassa are present. The great constituents of the pure muscular tissue are,—fibrin, and probably osmazome;—the gelatin met with being ascribable to the areolar membrane that envelopes the muscular fibres and lacerti. The membranous structures of young animals contain a much greater quantity of jelly than those of the adult; and it is probably on this account, that the flesh of the former is more gelatinous; not because the muscular fibre contains more gelatin. M. Thénard assigns the muscles, on final analysis, the following constituents:—fibrin; albumen; osmazome; fat; substances capable of passing to the state of gelatin; acid (lactic), and different salts: kreatin and kreatinin have likewise been found in them. They have also been analyzed by Berzelius and Braconnot[2] and others. It must be borne in mind, however, as M. Raspail[3] has properly remarked, that all these are the results of the analysis of muscle, as we meet with it. The analysis of muscular fibre has yet to be accomplished. In this, too, and every analogous case, the analysis only affords us evidence of the constituents of dead animal matter; and some of the products may even have been formed by new affinities resulting from the operations of the analyst. They can afford but an imperfect judgment of the constitution of the living substance. These remarks are especially applicable to the efforts at determining the composition of muscle by ultimate analysis. Mulder,[4] indeed, affirms, that this is impracticable—"for in this process we burn a mixture of

[1] Annales de Chimie, lvi. 43.

[2] Müller's Handbuch der Physiologie, Baly's translation, Part i. p. 369, Lond., 1837; and Dr. T. Thomson, Chemistry of Animal Bodies, p. 273, Edinb., 1843.

[3] Op. citat., p. 214.

[4] The Chemistry of Vegetable and Animal Physiology, by Fromberg, &c., p. 589, Edinb. and Lond., 1849.

various substances, a very complicated tissue of muscular fibres, ligamentary tissue, coats of bloodvessels and nerves. If, therefore, Playfair and Böckmann have found the composition of muscle to be identical with that of blood,—which is a mixture of various substances, containing some that are entirely different from those of muscle, and in which again others are wanting that are present in the latter,—then this may be considered as a proof that it is impossible to find out essential differences by means of ultimate analysis:"—and he adds—"Nothing has ever surprised me more than the assertions now so frequently repeated, that muscle and blood are identical in composition,—two substances which present, in fact, no other point of resemblance, except this, that they both contain protein compounds. But if we proceeded upon this principle, we should be induced at present to apply the term identity to a great number of substances indeed."

Muscular structure is liable, under particular circumstances, to a singular kind of conversion, to which it may be well to advert. When, about the latter part of the last century, it was determined, for purposes of salubrity, to remove the bodies from the churchyard of *Les Innocens* at Paris[1]—which had been the cemetery for a considerable part of the population of Paris for centuries, the whole area, occupying about seven thousand square yards, was found converted into a mass, consisting chiefly of animal manner, and raising the soil several feet above the natural level. On opening the ground, to remove the prodigious collection of dead bodies, they proved to be strangely altered in their nature and appearance. What had constituted the soft parts of the body was converted into an unctuous matter, of a gray colour, and peculiar, but not highly offensive, smell. According to their position in the pits,—for the bodies were deposited in pits or trenches, about thirty feet deep, each capable of holding from twelve hundred to fifteen hundred,—and according to the length of time they had been deposited, this transformation had occurred to a greater or less extent. It was found to be most complete in those that were nearest the centre of the pits, and when they had been buried about three years. In such case, every part, except the bones, hair and nails, seemed to have lost its properties, and to be converted into *gras des cimetières*, which was found to be a saponaceous compound, consisting of ammonia, united to *adipocire*,—a substance, as its name imports, possessing properties intermediate between those of fat and wax. When the adipocire was freed from the ammonia, and obtained in a state of purity, it was found to resemble strongly spermaceti, both in physical and chemical qualities. It was afterwards discovered, that the conversion of muscular flesh into adipocire might be caused by other means. Simple immersion in cold water, especially in a running stream, was found by Dr. Gibbes[2] to produce the conversion more speedily than inhumation. It can be caused, too, still more rapidly by the action of dilute nitric acid.

The chemical is not the only interest attached to this substance. It has been adduced in a court of justice for the purpose of enabling

[1] Thouret, Journal de Physique, xxxviii. 255.
[2] Philosophical Transactions for 1794 and 1795.

some judgment to be formed regarding the time that a body may have been immersed in the water. It is probable that this must differ greatly according to various circumstances;—as the period that elapsed between the death of the individual, and the act of immersion; the conditions of the fluid as to rest or motion, temperature, &c.; and the temperature of the atmosphere; so that any effort to fix a time for such conversion must be liable to much inconclusiveness. Yet the opinion of a medical practitioner on the subject has been the foundation of a juridical decision. At the Lent assizes, holden at Warwick, England, in the year 1805, the following case came before the court. A gentleman, who was insolvent, left his home with the intention,—as was presumed from his previous conduct and conversation,—of destroying himself. Five weeks and four days after that period, his body was found floating down a river. The face was disfigured by putrefaction, and the hair separated from the scalp on the slightest pull; but the other parts of the body were firm and white, without any putrefactive appearance. On examining the body, it was found that several parts were converted into adipocire. A commission of bankruptcy having been taken out against the deceased a few days after he left home, it became an important question to the interest of his family to ascertain whether or not he was living at that period. From the changes sustained by the body, it was presumed, that he had drowned himself on the day he left home; and to corroborate the presumption, the evidence of Dr. Gibbes was requested, who, from his experiments on this subject, it was thought, was better acquainted with it than any other person. Dr. Gibbes stated on the trial, that he had procured a small quantity of this fatty matter, by immersing muscular parts of animals in water for a month, and that it required five or six weeks to form it in any large quantity. Upon this evidence, the jury were of opinion, that the deceased was *not alive* at the time the commission was taken out, and the bankruptcy was accordingly superseded![1]

b. *Bones.*

The bones are the hardest parts of the animal frame; and serve as a base of support and attachment to the soft parts. They constitute the framework of the body, and determine its general shape. The principal functions they fulfil are,—to form defensive cavities for the most important organs of the body,—the encephalon, spinal-marrow, &c.—and to act as so many levers for transmitting the weight of the body to the soil, and for the different locomotive and partial movements. To them are attached the different muscles, concerned in those functions. In man and the higher classes of animals, the bones are, as a general rule, within the body; his *skeleton* is, consequently, said to be internal. In the crustacea, the testaceous mollusca, and certain insects the skeleton is external; the whole of the soft parts being contained within it. The lobster and crab are familiar instances of this arrangement.

The stature of the human skeleton is various, and may be taken, on

[1] Male, Epitome of Forensic Medicine, in Cooper's Tracts on Medical Jurisprudence, Philad., 1819.

the average, perhaps,—in those of European descent,—at about five feet seven and a half inches.[1] We find, however, examples of considerable variation from this average. A skeleton of an Irish giant, in the museum of the Royal College of Surgeons of London, measures eight feet four inches. On the other hand, Bebe, the dwarf of Stanislaus, King of Poland, was only thirty-three inches high; and a Polish nobleman, Boruwlaski, is said to have measured twenty-eight French inches, at twenty-two years of age. Mr. Mathews, the comedian, states, however, that he measured him late in life and found that his height was three feet three inches; and that he had undoubtedly grown an inch a short time before he was eighty-one, when he measured three feet four.[2] He had a sister, whose height was twenty-one inches.[3] Sir George Simpson,[4] in one of the villages of Siberia, saw a dwarf, about forty years of age, thickset, with a large head, and barely two feet and a half high. "For his inches, however," says Sir George, "he was a person of great importance, being the wise man of the place, and the great arbiter in all disputes, whether of love or of business." The celebrated dwarf, called General Tom Thumb, was seen by the author in 1847. He was then said to be fifteen years old; weighed at the Mint twenty pounds and two ounces, and was twenty-eight inches high. His intellect was evidently limited, childlike.

The bones may be divided into *short*, *broad* or *flat*, and *long*. *Short* bones are met with in parts of the body, which require to be both solid and movable:—in the hands and feet, for example; and in the spine. *Flat* or *broad* bones form the parietes of cavities, and aid materially in the movements and attitudes, by affording an extensive surface for the attachment of muscle. *Long* bones are chiefly intended for locomotion; and are met with only in the extremities. The shape of the *body* or *shaft* and of the *extremities of a bone* merits attention. The shaft or middle portion is the smallest in diameter, and is usually cylindrical. The extremities, on the other hand, are expanded; a circumstance, which not only adds to the solidity of the articulations, but diminishes the obliquity of the insertion of the tendons, passing over them, into the bones. In their interior is a medullary canal or cavity, which contains the *medulla*, *marrow* or *pith*:—a secretion, whose office will be a theme for after inquiry. One great advantage of this canal is, that it makes the bone a hollow cylinder, and thus diminishes its weight. On many of the bones, prominences and cavities are perceptible. The eminences bear the generic name of *apophyses* or *processes*. Their great use is to cause the tendons to be inserted at a much greater angle into the bones they have to move. It may be seen, hereafter, that the nearer such insertion is to the perpendicular to the lever, the greater will be the effect produced.

[1] Quetelet, Sur l'Homme, &c., Paris, 1835; or translation by Dr. Knox, p. 64, Edinb., 1842.

[2] A Continuation of the Memoirs of Charles Mathews, Comedian, by Mrs. Mathews, Amer. edit., i. 165, Philad., 1839: other cases are referred to by Isid. Geoffroy Saint-Hilaire, Histoire Générale et Particulière des Anomalies de l'Organisation chez l'Homme et les Animaux, i. 101, Bruxelles, 1837; and by Brachet, Physiologie Élémentaire de l'Homme, 2de édit., ii. 480, Paris et Lyon, 1855.

[3] Lectures on Physiology, Zoology, &c., by W. Lawrence, p. 434, Lond., 1819.

[4] An Overland Journey round the World, Amer. edit., Part ii. p. 203, Philad., 1847.

The cavities are of various kinds. Some are *articular:* others for the insertion, reception, or transmission of parts. Those of insertion and reception afford space for attachment of muscles; those of transmission, &c., are frequently incrusted with cartilage; converted into canals by means of ligament, and furnished with a synovial membrane, which lubricates them, and facilitates the play of the tendons, for the passage of which they are destined.

The mechanical structure of bone is a laminated framework incrusted by an earthy substance, and penetrated by exhalant and absorbent vessels, arteries, veins, and nerves. M. Herissant[1] appears to have been one of the first who stated, that bone is essentially composed of two substances:—the one a cartilaginous basis or parenchyma, giving form to the part;—the other a peculiar earthy matter deposited on this basis, and communicating to it hardness. These two constituents can be readily demonstrated; the first, by digesting the bone in dilute chlorohydric acid, which dissolves the earthy part, without acting on the animal matter; and the second, by burning the bone until all the animal matter is consumed, whilst the earthy is left untouched.

If we take a long bone and divide it longitudinally, we find that it is composed of three different substances, all of which may, however, be regarded as the same osseous tissue in various degrees of condensation. These are,—the *hard* or *compact* substance; the *spongy* or *areolar;* and the *reticulated.* The first is in the most condensed form; it exists at the exterior of the bone, and constitutes almost the whole of the shaft. The second is seen towards the extremities of a long bone, and in almost the whole of the short bones. In it, the laminæ are less close, and have a cancellated appearance,—the cellules bearing the name of *cancelli.* The reticulated substance is a still looser formation; the laminæ being situate at a considerable distance; and the space between filled up with a series of membranous cells, which lodge the marrow. The marginal figures represent a longitudinal and a transverse section of the same bone, in which this arrangement is well exhibited.

We have seen the advantages of the expanded extremities of long bones, as regards the insertion of muscles; but it is obvious, that if these portions of the bone had consisted of the heavy compact tissue, the increased weight would have destroyed the advantages, that would otherwise have accrued; whilst, if the shaft of the bone, exposed, as it is, to external violence, had consisted of the spongy tissue only, it would not have offered the necessary resistance. It is, therefore, formed almost entirely of the compact tissue; so that a section of one inch, taken from the body of the bone, will not differ essentially in weight from an inch taken from the extremity. Nor does the cavity within the bones diminish their strength, as might at first sight be presumed. By enlarging the circumference, the contrary effect is produced; for we shall see, in the mechanical proem to the particular movements, that of two hollow columns, formed of an equal quantity of matter and of the same height, that, which has the larger cavity, is actually the stronger. A very important use of the cancellated or spongy texture of the bones was suggested by a distinguished individual of

[1] Mémoir. de l'Académ. des Sciences de Paris, pour 1758, p. 322.

this country, to whom surgical science, in particular, has been largely indebted. Dr. Physick[1] asserts, that it serves to diminish, and, in many cases, to prevent, concussion of the brain, and of other viscera, in falls and blows. The demonstration, which he gives of this, is simple and satisfactory. If we suspend a series of six ivory balls by threads; raise the ball at one extremity of the series, and allow it to fall on the next to it, the farthest ball in the series is impelled to a distance which corresponds with the momentum communicated by the first ball to the second. But if we substitute, for the middle ball of the series, a ball made of the cellular structure of bone, almost the whole of the momentum is lost in this osseous structure; especially, if it be previously filled with tallow or well soaked in water, so as to bring it to a closer approximation to the living condition.

Fig. 349.

Sections of a Bone.

1, 2. Longitudinal section of the extremity.
3. Transverse section of the body.

Bones consist of earthy salts, and animal matter, intimately blended. The latter is chiefly cartilage, gelatin, and the peculiar fatty matter—the marrow. On reducing bones to powder, and digesting them in water, the fat rises and swims upon the surface; and the gelatin is dissolved. According to the analysis of Berzelius, 100 parts of dry human bones consist of animal matter, 33·3; basic phosphate of lime, 51·04; carbonate of lime, 11·30; fluoride of calcium, 2; phosphate of magnesia, 1·16; soda, chloride of sodium, and water, 1·2. It has been much doubted, however, whether fluoride of calcium is contained in recent bones; whilst it is admitted to have been detected in fossil bones. According to Dr. Daubeny,[2] it exists in the former, in about a quarter of the proportion in which it is present in the latter; but the proportions in different specimens of both kinds are variable. Dr. Daubeny ascribes the failure of those who have not detected fluorine except in fossil bones and teeth to the tenacity with which it is retained by animal matter; and to its being carried off with the carbonic acid evolved at the same time, too rapidly to act upon glass exposed to it. He, therefore, before submitting the bones to the action of strong sulphuric acid, burns away all the animal matters; removes the carbonic acid by dissolving them in chlorohydric acid; then throws down the earthy phosphates by caustic ammonia, and dries them.

MM. Fourcroy and Vauquelin found in bones oxides of iron and manganese, silica, and albumen. Mr. Hatchett detected, also, a small

[1] Horner, Special and General Anatomy, &c., 8th edit., i. 83, Philad., 1851.
[2] Philosophical Magazine, Aug., 1844.

quantity of sulphate of lime. Schreger gives the following as the proportions of animal and earthy parts:

	Infants.	Adults.	Aged.
Animal matter	47·20	20·18	12·20
Earthy matter	48·48	74·84	84·10
	95·68	95·02	96·30

The following are the average proportions, according to Lehmann,[1] from his own analyses, and those of two other observers.

	Sebastian.	Lehmann.	Frerichs.	
			Compact Bone.	Spongy Bone.
Organic	63·66	32·28	31·2	37·82
Earthy	63·34	67·72	68·8	62·18

Dr. Stark[2] affirms, from the results of his experiments, that the mean proportion of animal matter in the bones of all vertebrate animals is 33·91; of earthy 66·09; the mean proportion in the bones of man 33·39 of animal matter; 66·61 of earthy.

The bones are enveloped by a dense fibrous membrane, termed, in the abstract, *periosteum;* but assuming different names according to the part it covers. On the skull, it is called *pericranium:* and its extensions over the cartilages of prolongation are called *perichondrium.* The chief uses of this expansion are, to support the vessels in their passage to and from the bone, and to assist in its formation; for we find, that if the periosteum be removed from a bone, it becomes dead at the surface previously covered by the membrane, and exfoliates. In the fœtus, it adds materially to the strength of bone, prior to the completion of ossification. In the long bones, ossification commences at particular points; one generally in the shaft, and others at the different articular and other processes. These ossified portions are, for some time, separated from each other by the animal matter, which alone composes the intermediate portions of the bone; and, without this fibrous envelope, they would be too feeble, perhaps, to resist the strains to which they are exposed. The periosteum, moreover, affords a convenient insertion for muscles destined to act upon bones; and enables them to slide more readily when contracting: hence friction is avoided.

The cavity of long bones is lined by a membrane—called *medullary membrane* or *internal periosteum*—which is supplied with numerous vessels; adheres to the internal surface of bone, and is not only concerned in its nutrition, but in the secretion of the *marrow*, and likewise of a kind of oily matter, which differs from marrow in being more fluid, and is contained in cells formed by the spongy substance, and in areolæ of the compact substance. This is called *oil of bones.*

Marrow is considered to be lodged in membranous cells, formed by an extension of the internal periosteum; whilst, according to Mr. Howship,[3] oil of bones is probably deposited in longitudinal canals—*Haversian canals*— which traverse the solid substance of the bone, and through which its vessels are transmitted. If a thin transverse section of long

[1] Schmidt's Jahrbucher, No. vi., 1843.
[2] Edinburgh Medical and Surgical Journal, April, 1845, p. 313.
[3] Medico-Chirurg. Transact., vii. 393.

bone be examined under a high magnifying power, the bony matter is observed to be arranged in concentric circles around the orifices of the canals as in Fig. 351. These circles are marked by a number of stellated dark spots formerly termed *osseous corpuscles;* but as they are minute cavities in the bony substance, now more appropriately called *lacunæ.* From these, fine pores or tubes, termed *canaliculi*, proceed, which traverse the substance of the bone, and communicate irregularly with each other. All the different lacunæ communicate by means of the canaliculi with the Haversian canals; so that fluid may pass to every part of the osseous substance, and thus convey fluid for nutrition. They open, likewise, into the great medullary canal, and into the cavities of the cancellated texture. Blood corpuscles cannot pass along them, as their largest diameter has not seemed to be more than from 1-20000th to 1-14000th of an inch; and the smallest not more than from 1-60000th to 1-40000th.

Fig. 350.

Haversian Canals, seen on a Longitudinal Section of the Compact Tissue of the Shaft of one of the Long Bones.

1. Arterial canal. 2. Venous canal. 3. Dilatation of another venous canal.

The nature and fancied uses of marrow and oil of bones have been considered elsewhere.

The bones, periosteum, and marrow are, in the sound state, amongst the insensible parts of the frame. They are certainly not sensible to ordinary irritants; but, when morbid, exhibit intense sensibility. This applies, at least, to bones and the periosteum; the sensibility, which has been ascribed to the marrow, in disease, being probably owing to that of the prolongations of the membrane in which it is contained.

The number of the bones in the body is usually estimated at two hundred and forty, exclusive of the *sesamoid*, which are always found in pairs at the roots of the thumb and great toe; between the tendons of the flexor muscles and joints; and, occasionally, at the roots of the fingers and small toes.

The bones are connected by means of *articulations* or *joints*, which differ materially from each other. To all the varieties, names are appropriated, which form a difficult task for the memory of the anatomical student. Technically, every part at which two bones meet, and are connected, is called an *articulation*, whether any degree of motion exists or not. This, indeed, is the foundation of the division that prevails at the present day,—the articulations being separable into two classes; the *immovable* or *synarthroses*, and the *movable* or *diarthroses*. *Synarthroses* are variously termed, according to their shape. When the articular surfaces are dovetailed into each other, the joint is called a *suture*. This is the articulation that prevails in the bones of the skull. *Harmony* is when the edges of bones are even, and merely touch; as in the bones of the head in quadrupeds and birds. When a pit in one bone receives the projecting extremity of another, we have a case of *gomphosis*. It is exhibited in the union between the teeth

and their sockets. Lastly, *schindylesis* is when the lamina of one bone is received into a groove of another; as in the articulation of the vomer, which separates the nasal fossæ from each other. The *movable articulations* comprise two orders:—*amphiarthroses*, in which the two bones are intimately united by an intermediate substance, of a soft

Fig. 351.

Transverse Section of Compact Tissue of Humerus magnified about 150 diameters.

Three of the Haversian canals are seen, with their concentric rings; also the corpuscles or lacunæ, with the canaliculi extending from them across the direction of the lamellæ. The Haversian apertures had got filled with debris in grinding down the section, and therefore appear black in the figure, which represents the object as viewed with transmitted light.

and flexible character, as in the junction of the vertebræ with each other; and *diarthroses*, properly so called. The last admit of three subdivisions—*enarthroses* or *ball and socket joints;* the *condyloid* in which, owing to the head being oval, the movements are not as easy in all directions as when it is spherical; and the *ginglymoid* or *ginglymus*, in which the motion can occur in only one direction, as in a hinge. The farther subdivision of the joints belongs more to anatomy than to physiology.

The articular surfaces of bones never come into immediate contact. They are tipped with a firm, highly elastic substance, called *cartilage;* which, by its smoothness, enables the bones to move easily upon each other; and may have some influence in deadening shocks, and defending the bones, which it covers. The arrangement of cartilage varies according to the shape of the extremity of the bone. If it be spherical, the cartilage is thick at the centre, and gradually diminishes towards the circumference. In the cavity, the reverse is the case; the cartilage is thin at the centre, and becomes thicker towards the circumference; whilst on a trochlea or pulley its thickness is nearly every where alike.

An admirable provision against displacement of bones at the articulations is seen in the ligaments. These, by the French anatomists, are distinguished into two kinds—*fibrous capsules*, and *ligaments* properly

so called. The former are a kind of cylindrical sac, formed of a firm, fibrous membrane; open at each extremity, by which they closely embrace the articular ends of bones; and loose, when the joint admits of much motion. In this way, the articulation is completely enclosed: they generally bear the name of *capsular ligaments*. The *ligaments*, properly so called, are bands of the same kind of tissue, which extend from one bone to another; by their resistance preserving the bones *in situ;* and by their suppleness admitting the necessary motion.

The interior of all these articulations is lubricated by a viscid fluid, called *synovia*. This is secreted by a peculiar membrane of a serous nature; and its use is to diminish friction, and, at the same time, to favour adhesion. The mode in which it is secreted, and its chief properties and uses, will be the subject of future inquiry.

In certain of the movable articulations, fibro-cartilaginous substances, frequently called *interarticular cartilages*, are found between the articular surfaces, and not adherent to either. These have been supposed to form a kind of cushion, which, by yielding to pressure, and returning upon themselves, may protect the joints to which they belong; and, accordingly, it is asserted, that they are met with in joints, which have to sustain the greatest pressure; but M. Magendie[1] properly remarks, that they do not exist in the hip or ankle-joint, which have constantly to support the strongest pressure. The use, which he suggests, is more specious;—that they may favour the extent of motion, and prevent displacement.

The stability of the joints is likewise aided by the manner in which muscles or tendons pass over them. These are contained in an aponeurotic sheath, to prevent their displacement; and thus the whole limb becomes well protected, and dislocation unfrequent, even in those joints, as that of the shoulder, which, as regards their osseous arrangement, ought to be very liable to displacement.

It has been suggested by Weber, that the head of the thigh-bone is retained *in situ*, not by the power of the muscles or ligaments but by the pressure of the surrounding atmosphere; and Lauer,[2] who repeated Weber's experiments under the directions of Fricke, of Hamburg, is of opinion, that atmospheric pressure must be classed among the means by which the lower extremity is kept in apposition with the trunk of the body.

2. PHYSIOLOGY OF MUSCULAR MOTION.

By *voluntary motion* or that effected by the *muscular system of animal life*, we mean contraction of the muscles under the influence of *volition* or *will*. This influence is propagated along the nerves to the muscles, which are excited by it to contraction. The *encephalon*, *spinal marrow*, *nerves*, and *muscles* are, therefore, organs of voluntary muscular contraction.

Volition is a function of the encephalon, and might have been with much propriety included under the physiology of the intellectual and moral acts; but as it is so intimately concerned with muscular motion, it was judged advisable to defer its consideration. That in man and

[1] Précis Élémentaire, 2de édit., i. 292, Paris, 1823.
[2] Zeitschrift fur die gesammte Medicin, Band ii. Heft 3.

the higher animals, it is a product of encephalic action is proved by many facts. If the brain be injured in any manner;—by fracture of the skull, or by effusion of blood, producing apoplectic pressure;—or if it be deprived of its functions by a strong dose of any narcotic substance;—or if, again, it be in a state of rest, as in sleep:—volition is no longer exerted; and voluntary motion is impracticable. This is the cause why the erect attitude cannot be maintained during sleep; and why the head falls forward upon the chest, when somnolency is to such an extent as to deprive the extensor muscles of the back and head of their stimulus to activity.[1] That an emanation from the encephalon is necessary is likewise proved by the effect of tying, cutting, compressing, or stupefying a nerve proceeding to a muscle: it matters not that the will may act; the muscle does not receive the excitation, and no motion is produced; a fact which proves, that nerves are the channels of communication between the brain and the muscles. If, again, we destroy the medulla oblongata and medulla spinalis, we abolish all muscular motion, notwithstanding the brain may will, and the muscles be in a state of physical integrity; because we have destroyed the parts whence the nerves proceed. In like manner, by successively slicing away the medulla spinalis from its base to the occiput, we paralyse, in succession, every muscle of the body that receives its nerves from the spinal marrow.

Experiments of physiologists have confirmed the view, that the encephalon is the chief seat of volition. When it has been sliced away to a certain extent, the animal has been thrown into a state of stupor, attended with loss of sensibility, power of locomotion, and especially spontaneous motion; and in writing, dancing, speaking, &c., we have indisputable evidence of its direction by the intellect. It is not so clear, that the seat of volition is restricted to the encephalon. There are actions of the yet living trunk, which appear to show, that an obscure volition may be exerted even after the brain has been separated from the rest of the body; and acephalous children have not only moved perceptibly when in utero, but at birth. Without referring to the lowest classes of animals, which execute voluntary motions for a long time after they have been bisected, every one must have noticed the motions of decapitated fowls, which continue for a time, to run and leap, and apparently, to suffer uneasiness in the incised part.

The feats of the Emperor Commodus are elucidative of this matter. Herodian relates, that he was in the habit of shooting at the ostrich, as it ran across the circus, with an arrow having a cutting edge; and, even when the shaft was true to its destination, and the head was severed from the body, it usually ran several yards before it dropped. Kaauw Boerhaave—nephew of the celebrated Hermann, himself an eminent medical teacher at St. Petersburg—asserts that he saw a cock, thus decapitated, run a distance of twenty-three feet. Cases are also recorded of men walking a few steps after decapitation, striking their breasts, &c.; but they can scarcely be regarded as authentic.[2] In

[1] Adelon, art. Encéphale (Physiol.) in Dict. de Méd., vii. 516, Paris, 1823; and Physiol. de l'Homme, ii. 25, 2de édit., Paris, 1829.

[2] Adelon, op. citat., ii. 28; and Dr. J. R. Coxe, in Dunglison's Amer. Med. Intelligencer, for May 15, 1837.

countries where judicial execution consists in decapitation by the sword, sufficient opportunities must have presented themselves for testing this question; but no zealous Naturforscher appears to have been present to record them. Similar opportunities have likewise occurred under the operations of the guillotine.

M. Legallois,[1] in some experiments, which he instituted, for the purpose of determining the nervous influence on the heart, &c., found that rabbits, which he had deprived of their heads and hinder extremities, but still kept alive by artificial respiration, moved their fore paws whenever he stimulated them by plucking their hairs.

With regard to complete acephali, or those fœtuses which are totally devoid of encephalon,—although they may vegetate in utero, they expire after birth, owing to their being devoid of the medulla oblongata in which is the nervous system of respiration. Monsters have been born without the brain, but with part of the encephalon. These have been called, by way of distinction, *anencephali* or *hemicephali*. Where the medulla oblongata exists, they possess the nervous system of the senses, and of respiration, and are, consequently, able to live for a time after birth, and to exert certain muscular movements, as sucking, moving the limbs, evacuating the excretions, &c. M. Adelon asserts, that none of these facts ought to shake the proposition,—that in the superior animals, and consequently in man, the medulla spinalis and nerves are merely the conductors of volition or the locomotive will; and that volition is produced in the encephalon alone. His arguments on this point are not, however, characterized by that ingenuousness and freedom from sophism, for which his physiological disquisitions are generally distinguished. "First of all," he observes, "the fact of the progression and motions of men and quadrupeds after decapitation is manifestly apocryphal; and even if we admit, that certain animals still execute certain movements after decapitation, are such evidently regular and ordained? And, supposing them to be so, may not this have arisen from the conformation of the parts, or from habits contracted by the organs? This last appears to us most probable; for if, from any cause whatever, the muscles of a part contract, they cause the part to execute such motions as the joints, entering into its composition, require; and which may, therefore, be similar to those produced by the will." He further attempts to deny the facts related of the lower classes of animals, and asserts, that "they are not evinced in the experiments instituted in our day." The cases, recorded to prove the defective sensibility of the lower tribes of animated nature, are, however, as has been elsewhere shown, incontestable.—The trunk of the wasp attempts to sting after the head has been removed; and an experiment made on the rattlesnake by Dr. Harlan,[2] in the presence of Capt. Basil Hall, certainly demonstrates something like design in the headless trunk; and the cases, already referred to, on the authority of Drs. Le Conte and Dowler, exhibit almost miraculous phenomena of the kind in the decapitated alligator.[3]

Our conclusion ought probably to be, from all these cases,—that

[1] Œuvres, Paris, 1824. [2] Medical and Physical Researches, Philad., 1835.

[3] See p. 153 of this volume.

volition is chiefly seated in the encephalon, but that an obscure action of the kind may originate, perhaps, farther down the cerebro-spinal axis. This conclusion, of course, applies only to the higher classes of animals; for we have seen, that the polypus is capable of division into several portions, so as to constitute as many distinct beings; and it is probable, that the principal seat of volition may extend much lower in the inferior tribes of created beings.

Successful attempts have been made to discover, whether the whole brain is concerned in volition, or only a part. Portions have been disorganized by disease, and yet the person has not been deprived of voluntary motion; at other times, as in paralysis, the faculty has been impaired; and again, considerable quantities of brain have been lost, owing to accidents (in one case the author knew nineteen tea-spoonfuls), with equal immunity as regards the function in question. Experiments, executed on this subject, go still farther to confirm the idea, that volition is not seated exclusively in the encephalon. MM. Rolando and Flourens[1] performed several, with the view of detecting the seat of the locomotive will, or of that which presides over the general movements of station and progression; and they were led to fix upon the cerebral lobes. Animals, from which these were removed, were thrown into a sleepy, lethargic condition; were devoid of sensation and spontaneous motion, and moved only when provoked. On the other hand, M. Magendie[2] affirms, that the cerebral hemispheres may be cut deeply in different parts of their upper surface, without any evident alteration in the movements. Even their total removal, if it did not implicate the corpora striata, he found to produce no greater effect; or, at least, none but what might be easily referred to the suffering induced by such an experiment. The results, however, were not alike in all classes of vertebrated animals. Those mentioned were observed in quadrupeds, and particularly dogs, cats, rabbits, Guinea pigs, hedgehogs, and squirrels. In birds, the removal or destruction of the hemispheres—the optic tubercles remaining untouched—was often followed by the state of stupor and immobility described by MM. Rolando and Flourens; but, in numerous cases, the birds ran, leaped, and swam, after the hemispheres had been removed, the sight alone appearing to be destroyed. In reptiles and fish, the removal of the hemispheres seemed to exert little effect upon their motions. Carps swam with agility; frogs leaped and swam as if uninjured; and their sight did not appear to be affected. Magendie[3] properly concludes from these experiments, that the spontaneity of the movements does not belong exclusively to the hemispheres; that in certain birds, as the pigeon, adult rook, &c., this seems to be the case; but not so in other birds. To mammalia, reptiles, and fish,—at least such of them as were the subjects of experiment,—his conclusion is, however, applicable.

Of the nature of the action of the brain in producing volition we know nothing. It is only in the prosecution of direct experiments on the encephalon that we can have an opportunity of seeing it during the execution of the function; but the process is too minute to admit of observation. Our knowledge is confined to the fact, that the encephalon

[1] Op. citat. [2] Précis Élémentaire. [3] Ibid., i. 336.

acts, and that some influence is projected from it along the muscles, which excites them to action; and accurately regulates the extent and velocity of muscular contraction. Yet volition is not the sole excitant of such contraction. If we irritate any part of the encephalon or spinal marrow, or any of the nerves proceeding from them, muscular movements are excited; but they are not regulated as when under the influence of volition. The whole class of *involuntary motions*, or rather of those executed by the *muscular system of organic life*, is of this kind, including the action of many of the most important organs,—heart, intestines, blood-vessels, &c. The involuntary muscles equally require a stimulus to excite them into action; but, as their name imports, they are removed from the influence of volition. In certain diseased conditions, we find, that all the voluntary muscles assume involuntary motions; but this is owing to the ordinary volition being interfered with, and to some direct or indirect stimulation affecting the parts of the cerebro-spinal axis concerned in muscular contraction; or, if the effect be local, to some stimulation of the nerve proceeding from the axis to the part. Of this kind of general involuntary contraction of voluntary muscles, we have a common example in the convulsions of children; and one of the partial kind in cramp or spasm.

The will, then, is the great but not the sole regulator of the supply of voluntary nervous influence. This is confirmed by experiment. If a portion of the spinal marrow be divided, so as to separate it from all communication with the encephalon, the muscles cannot be affected by the will; but they contract on irritating the part of the spinal marrow, from which its nerves proceed. It has, hence, been presumed by some physiologists, that volition is only the exciting and regulating cause of the nervous influx; and that the latter is the immediate agent in producing contraction; and they affirm, that as, in the sensations, the impression is made on the nerve, and perception effected in the brain,—so, in muscular motion, volition is the act of the encephalon, and the nervous influx to a part corresponds to the act of impression.

With regard to the seat of this nervous centre of muscular contraction, much discrepancy has existed amongst modern physiologists. It manifestly is not in the whole encephalon, as certain portions of it may be irritated in the living animal without exciting convulsions. Parts of it, again, may be removed without preventing the remainder from exciting muscular contraction when irritated. In the experiments of M. Flourens, the cerebral lobes were taken away, yet the animals, when stimulated, were susceptible of motion; and whenever the medulla oblongata was irritated, convulsions were produced. Its seat is not, therefore, in the whole encephalon. M. Rolando refers it to the cerebellum. He asserts, that on removing the cerebellum of living animals, without implicating any other part of the encephalon, they preserved their sensibility and consciousness, but were deprived of the power of motion. This occurred to a greater extent in proportion to the severity of the injury inflicted on the cerebellum. If the injury was slight, the loss of power was slight; and conversely. Impressed with the resemblance between the cerebellum of birds and the galvanic apparatus of the torpedo; and taking into consideration the lamellated structure of the cerebellum, which, according to him, re-

sembles a voltaic pile; and the results of his experiments, which showed, that the movements diminished in proportion to the injury done to the cerebellum, Rolando drew the inference, that this part of the encephalon is an electro-motive apparatus for the secretion of a fluid analogous to the galvanic. This fluid is, according to him, transmitted along the nerves to the muscles, and excites them to contraction. The parts of the encephalon concerned in volition would, in this view, regulate the quantity in which the motive fluid is secreted; and govern the motions; whilst the medulla oblongata, which, when alone irritated, always occasions convulsions, would put the encephalic extremity of the conducting nerves in direct or indirect communication with the locomotive apparatus.

This ingenious and simple theory is, however, far from being corroborated by the fact, mentioned by M. Magendie,[1] that he is annually in the habit of exhibiting to his class animals deprived of cerebellum, which are capable of executing regular movements. For example, he has seen the hedgehog and Guinea-pig, deprived not only of brain but of cerebellum, rub the nose with its paw, when a bottle of strong acetic acid was held to it; and he remarks, that a single positive fact of the kind is worth all the negative facts that could be adduced. He farther observes, that there could be no doubt of the entire removal of the brain in his experiments. The experiments of Magendie are, however, equally adverse to the hypothesis of M. Flourens, that the cerebellum is the *regulator* or *balancer* of the movements. Some anatomical observations by Mr. Solly[2] would seem to show, that there is a direct communication between the motor tract of the spinal marrow and the cerebellum. The corpora pyramidalia have been generally supposed to be formed by the entire mass of the anterior or motor columns of the spinal cord, but Mr. Solly shows, that not more than one-half of the anterior column enters into the composition of these bodies; and that another portion, which he terms "antero-lateral column," when traced on each side in its progress upwards, is found to cross the cord below the corpora olivaria, forming, after mutual decussation, the surface of the corpora restiformia; and being ultimately continuous with the cerebellum.

Others, again, have estimated the encephalon to be the sole organ of volition, and have referred the nervous action, which produces the "locomotive influx," as it is termed, exclusively to the spinal marrow; and hence they have termed the spinal marrow, and the nerves issuing from it, the "*nervous system of locomotion.*" It is manifest, however, that the encephalon must participate with the medulla spinalis in this function; inasmuch as not only does direct irritation of several parts of the former excite convulsions, but we see them frequently as a consequence of disease of the encephalon; yet, as has been remarked, there is some reason for believing, that, in the upper classes of animals, an obscure volition may be exercised for a time, even when the encephalon is separated from the body. It need scarcely be said, that

[1] Précis, &c., i. 340.

[2] Transactions of the Royal Society for 1836; and Solly on the Brain, Amer. edit., Phila., 1848.

we are as ignorant of the character of this influx as we are of that of the nervous phenomena in general.

The parts of the encephalon and spinal marrow, concerned in muscular motion, are very distinct from those that receive the impressions of external bodies. The function of sensibility is comprised in the medulla oblongata and in the posterior column of the spine, whilst the cerebro-spinal organs of muscular motion appear to be the corpora striata, the thalami nervorum opticorum, at their lower part; the crura cerebri; the pons Varolii; the peduncles of the cerebellum; the lateral parts of the medulla oblongata, and the anterior column of the medulla spinalis. This is proved by direct experiment, as will be shown presently; and, in addition to this, pathology furnishes us with numerous examples of their distinctness. In various cases of hemiplegia or palsy of one side of the body,—which is of encephalic origin,—we find motion almost lost; yet sensibility may be slightly or not at all affected; and, on the other hand, instances of loss of sensation have been met with, in which the power of voluntary motion has continued. Modern discoveries in the system of vertebral nerves exhibit how this may happen. A considerable space may exist between the roots of a nerve, one of which shall be destined for sensation, the other for motion; yet both may pass out enveloped in one sheath;—the same nervous cord thus conveying the two irradiations, if they may be so termed. According to Sir Charles Bell's system, the spinal column is divided into three tracts; the anterior for motion; the posterior for sensibility; and the two are kept separate and united by the third—the column for respiration. The existence of the last column is now admitted by few.[1]

The experiments performed by the French physiologists especially,—for the purpose of discovering the precise parts of the encephalon concerned in muscular motion,—have attracted great and absorbing interest. We wish it could be said, that the results have been such as to afford determinate notions on the subject. According to those of M. Flourens, the cerebral lobes preside over volition, and the medulla oblongata over the locomotive influx: to the latter organ he assigns, also, sensibility. We have seen, that the results of his experiments have been contested; and with them, of course, his deductions. The facts and arguments, already stated, throw doubts on all except the last proposition, which refers sensibility to the medulla oblongata; and even it is not restricted to that organ, or group of organs, whichsoever it may be considered.

MM. Foville and Pinel Grand-Champ[2] have affirmed that the cerebellum is the seat of sensibility. To this conclusion they were led by the remarks they had made, in the course of their practice, that the cases of paralysis of sensibility, which fell under their notice, succeeded more especially to morbid conditions of the encephalon. In this view they conceive themselves supported by the discovery of columns in the spinal marrow destined for particular functions; and, as the postero-lateral column is found to be the column of sensibility, and the cerebellum seems to be formed from this column, they think it ought to be possessed of the same functions. M. Adelon[3] remarks,

[1] See vol. i. p. 643. [2] Sur le Système Nerveux, Paris, 1820. [3] Op. citat., ii. 38.

that Willis professed a similar notion, and that he considered the cerebral lobes to be the point of departure for the movements, and the cerebellum the seat of sensibility. In his first volume, however, he had cited more correctly the views of Willis. "Willis says positively," he remarks, "that the corpora striata are the seat of *perception;* the medullary mass of the brain, that of *memory* and *imagination;* the corpus callosum, that of *reflection;* and the cerebellum, the source of the *motive spirits*." Willis, in truth, regarded the cerebellum as supplying animal spirits to the nerves of involuntary functions, as the heart, intestinal canal, &c. The opinions of Foville and Pinel Grand-Champ are, however, subverted by the experiments of Rolando, Flourens, and Magendie, which show, that sensation continues, notwithstanding serious injury to, and even entire removal of, the cerebellum.

By other physiologists, the two functions have been assigned respectively to the cineritious and medullary parts of the brain; some asserting, that the seat of sensibility is more especially in the latter, and the motive force in the former. According to Treviranus, the more medullary matter an animal has in its brain and spinal marrow, in proportion to the cineritious, the greater will be its sensibility. To this, however, M. Desmoulins[1] objects, that in many animals, the spinal marrow is composed exclusively of medullary matter [?]; and consequently they ought not only to be the most sensible of all, but to be wholly devoid of the power of motion. Others, again, as MM. Foville and Pinel Grand-Champ have reversed the matter; assigning sensibility to the cineritious substance, and motility to the medullary. From these conflicting opinions, it is obviously impossible to sift anything categorical; except that we are ignorant of the special seat of these functions. A part of the discrepancy in the results must be ascribed to organic differences in the animals which were the subjects of the experiments. This was strikingly exemplified in those instituted by M. Magendie, which have been cited. Similar contrariety exists in the experiments and hypotheses, regarding the particular parts of the encephalon that are concerned in determinate movements of the body. The results of many of those are, indeed, so strange, that did they not rest on eminent authority they might be classed among the romantic.

It has been already remarked, that Rolando considered the cerebellum to be an electro-motive apparatus, producing the whole of the galvanic fluid necessary for the motions. M. Flourens, on the other hand, from similar experiments, independently performed, and without any knowledge of those of Rolando, affirmed it to be the regulator and balancer of the locomotive movements; and he asserted, that, when removed from an animal, it could neither maintain the erect attitude, nor execute any movement of locomotion; nor, although possessing all its sensations, could it fly from danger it saw menacing it. The same view has been advocated by M. Bouillaud, who has detailed eighteen experiments in which he cauterized the cerebellum, and found that, in all, the functions of equilibration and progression were disordered. The

[1] Anatomie des Systèmes Nerveux, &c., Paris, 1825.

experiments of M. Magendie[1] on this subject are pregnant with important novelty. We have already referred to those that concern the cerebral hemispheres and cerebellum as the encephalic organs of the general movements, in the mode suggested by MM. Rolando and Flourens, and others. M. Magendie affirms, in addition, "that there exists, in the brain, four spontaneous impulses or forces, which are situate at the extremity of two lines cutting each other at right angles; the one impelling forwards; the second backwards; the third from right to left, causing the body to rotate; and the fourth from left to right, occasioning a similar movement of rotation." The first of these impulses he fixes in the cerebellum and medulla oblongata; the second in the corpora striata; and the third and fourth in each of the peduncles of the cerebellum.

1. *Forward Impulse.*—It has often been observed by those who have made experiments on the cerebellum, that injuries of it cause animals to recoil manifestly against their will. M. Magendie[2] asserts, that he has frequently seen them, when wounded in the cerebellum, make an attempt to advance, but be immediately compelled to run back; and he says that he kept a duck for eight days, the greater part of whose cerebellum he had removed, which did not move forwards during the whole of that time, except when placed on water. Pigeons, into whose cerebella he thrust pins, constantly walked and flew backwards, for more than a month afterwards. Hence, he concludes, that there exists, either in the cerebellum or medulla oblongata, a force of impulsion, which tends to cause animals to go forward. He thinks it not improbable, that this force exists in man; and states that Dr. Laurent, of Versailles, exhibited to him, and to the *Académie Royale de Médecine*, a young girl, who, in the attacks of a nervous disease, was obliged to recoil so rapidly, that she was incapable of avoiding bodies or pits behind her; and was, consequently, exposed to serious falls and bruises. This force, he affirms, exists only in the mammalia and birds;—certain fish and reptiles, on which he experimented, appearing to be unaffected by the entire loss of the cerebellum.

2. *Backward Impulse.*—M. Magendie found,[3] when the corpora striata were removed, that the animal darted forward with great rapidity; and if stopped, still maintained the attitude of running. This was particularly remarked in young rabbits; the animals appearing to be impelled forward by an inward and irresistible power, and passing over obstacles without noticing them. These effects were not found to take place, unless the white, radiated part of the corpora striata was cut: if the gray was alone divided, no modification was produced in the movements. If only one of the corpora was removed, the rabbit remained master of its movements, directed them in different ways, and stopped when it chose; but, immediately after the removal of the other, all regulating power over the motions appeared to cease, and it was irresistibly impelled forwards. In the disease of the horse, called, by the French, *immobilité*, the animal is often capable of walking, trotting, and galloping forward with rapidity; but he does not back; and frequently it is impracticable to arrest his motion forwards. M. Ma-

[1] Op. citat., i. 345. [2] Précis, i. 341. [3] Op. cit., i. 337.

gendie[1] asserts, that he has opened several horses that died in this condition; and found, in all, a collection of fluid in the lateral ventricles, which had produced a morbid change on the surface of the corpora striata, and must have exerted a degree of compression on them.

Similar pathological cases occur in man. M. Magendie relates the case of a person, who became melancholic, and lost all power over his movements; continually executing the most irregular and fantastic antics; and frequently compelled to walk exclusively forwards or backwards until stopped by some obstacle. In this case, recovery occurred; and, accordingly, there was no opportunity for investigating the encephalic cause. M. Itard describes two cases, in which the patients were impelled, in paroxysms, to run straight forward, without the power of changing their course, even when a river or precipice was before them. A case is related by M. Piédagnel,[2] which is more to the purpose as an opportunity occurred for *post mortem* examination. The subject of it also was irresistibly impelled to constant motion. "At the time of the greatest stupor," says M. Piédagnel, "he suddenly arose; walked about in an agitated manner; made several turns in his chamber, and did not stop until fatigued. On another occasion, the room did not satisfy him; he went out, and walked as long as his strength would permit. He remained out about two hours, and was brought back on a litter." M. Piédagnel adds, "that he seemed impelled by an insurmountable force," which kept him in motion, until his powers failed him. On dissection, several tubercles were found in the right cerebral hemisphere, especially at its anterior part; and at the side of the corpora striata. These had produced much morbid alteration in that hemisphere; and had, at the same time, greatly pressed on the other. From these facts, M. Magendie infers it to be extremely probable, that, in the mammalia and in man, a force of impulsion always exists, which tends to impel backwards, and is, consequently, the antagonist to the force seated in the cerebellum.

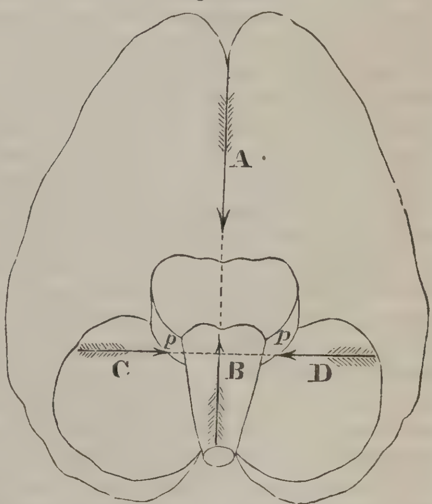
3. *Lateral Impulse.*—If the peduncles of the cerebellum—crura cerebelli—be divided in a living animal, it immediately begins to turn round, as if impelled by some considerable force. The rotation or circumgyration is made in the direction of the divided peduncle—M. Longet says, in the opposite direction—and, at times, with such rapidity, that the animal makes as many as sixty revolutions in a minute. The same kind of effect is produced by any vertical section of the cerebellum, which implicates from before to behind the whole substance of the medullary arch formed by that organ above the fourth ventricle; but the movement is more rapid, the nearer the section is to the origin of the peduncles; in other words to their point of junction with the pons Varolii. M. Magendie[3] affirms, that he has seen this movement continue eight days without stopping, and apparently without any suffering. When an impediment was placed in the way, the motion was arrested; and, under such circumstances, the animal frequently remained with its paws in the air, and ate in this attitude.

[1] Op. cit., i. 338.
[2] Magendie, Journal de Physiologie, tom. iii.; and Précis Élémentaire, i. 338.
[3] Précis, &c., i. 343.

What he conceives to have been one of his most singular experiments was,—the effect of the division of the cerebellum into two lateral and equal halves: the animal appeared to be alternately impelled to right and left, without retaining any fixed position: if he made a turn or two on one side, he soon changed his motion and made as many on the other. M. Serres[1]—who is well known as a writer on the comparative anatomy of the brain, and must have had unusual opportunities for observation at the Hospital *La Pitié* to which he was attached—gives the case of an apoplectic, who presented, amongst other symptoms, the singular phenomenon of turning round, like the animals in those experiments; and, on dissection, an apoplectic effusion was found in that part of the encephalon. On dividing the pons Varolii vertically, from before to behind, M. Magendie[2] found, that the same rotary movement was produced: when the section was to the left of the median line, the rotation was to the left, and conversely; but he could never succeed in making the section accurately on the median line. From these facts he concludes, that there are two forces, which are equilibrious by passing across the circle formed by the pons Varolii and cerebellum. To put this beyond all question, he cut one peduncle, when the animal immediately rolled in one direction; but on cutting the other or the one on the opposite side, the movement ceased, and the animal lost the power of keeping itself erect, and of walking.

From the results of all his experiments, M. Magendie infers, that an animal is a kind of automatic machine, wound up for the performance of certain motions, but incapable of producing any other. The figure of the base of the brain in the margin, will explain, more directly, the impulses described by this physiologist. The corpora striata are situate in each hemisphere, but their united impulses may be represented by the arrow A; the impulse seated in the cerebellum, by the arrow B; and those in each peduncle of the cerebellum, *p*, *p*, by the arrows C and D respectively. When the impulse backwards is from any cause destroyed, the animal is given up to the forward impulse, or that represented by the arrow B; and conversely. In like manner, the destruction of one lateral impulse leaves the other without an antagonist, and the animal moves in the direction of the arrow placed over the seat of the impulsion that remains. In a state of health, all these impulsions being

Fig. 352.



Direction of Encephalic Impulses, according to Magendie.

[1] Magendie's Journ. de Physiol., iv. 405.

[2] Précis, &c., p. 344.

nicely antagonized, they are subjected to the influence of volition; but in disease they may be so modified as to be entirely withdrawn from its control.

These four are not the only movements excited by particular injuries done to the nervous system. M. Magendie[1] states, that a circular movement to the right or left, similar to that of horses in a circus, was caused by the division of the medulla oblongata, to the outer side of the corpora pyramidalia anteriora. When the section was made on the right side, the animal turned, in this fashion, to the right; and to the left, if the section was made on that side.

The parts, according to Dr. Brown-Séquard,[2] which can be injured without producing turning are, the cerebral hemispheres, the cerebellum, the corpora striata, the corpus callosum, the spinal marrow, and the olfactory and optic nerves. Every other portion of the cerebro-spinal centres is able to produce turning or rolling. He found, also, that they were produced by tearing the facial nerve and by a puncture or section of the auditory nerve.

Pathology has, likewise, indicated the brain as the seat of different bodily movements. Diseases of the encephalon have been found not only to cause irregular movements or convulsions but paralysis of a part of the body, leaving the rest untouched. Hence it has been concluded, that every motion of every part has its starting point in some portion of the brain. The ancients were well aware, that in cases of hemiplegia, the encephalic cause of the affection is found in the opposite hemisphere. Attempts have been made to decide upon the precise part of the encephalon in which the decussation takes place. Many have conceived it to be in the commissures; but the greater number, perhaps, have referred it to the corpora pyramidalia. These, the researches of Gall and Spurzheim[3] and others, had pointed out as decussating at the anterior surface of the marrow, and as being apparently continuous with the radiated fibres of the corpora striata; and an opinion has prevailed, that the paralysis is of the same side as the encephalic affection, or of the opposite, according as the affected part of the brain is a continuation of fasciculi, which do not decussate—of the corpora olivaria, for example—or of the corpora pyramidalia, which do. M. Serres,[4] however, affirms, that affections of the cerebellum, pons Varolii, and tubercula quadrigemina, exert their effects upon the opposite side of the body, and he supports his statement by pathological cases and direct experiment. M. Magendie[5] divided one pyramid from the fourth ventricle; yet no sensible effect was produced on the movements; certainly, there was no paralysis, either of the affected or opposite side; he then divided both pyramids about the middle, and no apparent derangement occurred in the motions—a slight difficulty in progression being alone observable. The section of the posterior pyramids was equally devoid of perceptible influence on the general movements; and to cause paralysis of one half the body, it was necessary to divide the half of the medulla oblongata, when the corresponding

[1] Précis, &c., p. 345.
[2] Med. Examiner, August, 1852, p. 498.
[3] Recherches sur le Système Nerveux, &c., sect. vi., Paris, 1809.
[4] Anatomie Comparée du Cerveau, Paris, 1824.
[5] Op. cit.

side became,—not immovable, for it was affected by irregular movements; and not insensible, for the animal moved its limbs when they were pinched,—but incapable of executing the determinations of the will.

These views are not exactly in accordance with the general idea, that disease, confined to one hemisphere of the brain, or cerebellum, and to one side of the mesial plane in the tuber annulare, constantly affects the opposite side; whilst disease, confined to one of the lateral columns of the medulla oblongata and medulla spinalis, affects the corresponding side of the muscular system;—the encephalon having a crossed,—the medulla a direct effect.[1] The crossing of the fibres at the anterior surface of the marrow would not, however, account for the loss of sensation in hemiplegia. Mr. Hilton[2] has examined carefully the continuation upwards of the anterior and posterior columns of the spinal marrow into the medulla oblongata, and found, that the decussation at the upper part of the marrow belongs in part to the column for motion, and in part to the column for sensation; and farther, that the decussation is only partial with respect to either of the columns.

It has been elsewhere shown,[3] that the decussation of the sensitive nerve-fibres, in the opinion of Dr. Brown-Séquard,[4] takes place in the spinal cord; and the same observer infers from his experiments, that the voluntary nerve-fibres appear to make their whole decussation, or, at least, the greater part of it in the inferior portion of the medulla oblongata; and "not in the other parts of the isthmus of the encephalon," as has been imagined by many.

The result of the examination of morbid cases has induced some physiologists to proceed still farther in their location of the encephalic organs of muscular motion; and to attempt an explanation of paraplegia, or cases in which one half the body, under the transverse bisection, is paralyzed. MM. Serres, Foville, and Pinel Grand-Champ assert, that the anterior radiated portion of the corpora striata presides over the movements of the lower limbs; and the optic thalami over those of the upper; and that according as the extravasation of blood, in a case of apoplexy, occurs in one of these parts, or in all, the paralysis is confined to the lower or to the upper limbs, or extends over the whole body. In 1768, M. Saucerotte[5] presented a prize memoir to the *Académie Royale de Chirurgie*, of Paris, in which a similar view was expressed. He had concluded, from experiments, that affections of the anterior parts of the encephalon paralyse the lower limbs, whilst those of the posterior parts paralyse the upper. M. Chopart,—in a prize essay, crowned in 1769, and contained in the same volume with the last,—refers to the results of experiments by M. Petit, of Namur, which appeared to show, that paralysis of the opposite half of the body was not induced by injury of the cerebral hemisphere, unless the cor-

[1] Lectures on the Nervous System and its Diseases, by Marshall Hall, M. D., &c., Lond., 1836, p. 34, or Amer. edit., Philad., 1836.

[2] Proceedings of the Royal Society, No. 34, for 1837–8; also, Solly on the Brain, p. 145, Lond., 1836; and Dr. John Reid, Edinb. Med. and Surg. Journ., Jan., 1841, p. 12.

[3] Vol. i. p. 653.

[4] Experimental and Clinical Researches on the Physiology and Pathology of the Spinal Cord and some other parts of the Nervous Centres, p. 29, Richmond, 1855.

[5] Prix de l'Académie Royale de Chirurgie, vol. iv. p. 373, Paris, 1819.

pora striata were cut or removed. The experiments by Saucerotte were repeated by M. Foville, and are detailed in a memoir, crowned by the *Académie Royale de Médecine*, of Paris, in 1826. They were attended with like results. In cats and rabbits, he cauterized, in some, the anterior part of the encephalon; in others, the posterior: in every one of the former, paralysis of the posterior, and in the latter, of the anterior extremities succeeded. Having in one animal mutilated the whole of the right hemisphere, and only the anterior part of the left, he found that the animal was paralysed in the hinder extremities, and in the paw of the left fore-leg; but that the paw of the right remained active.[1]

Lastly, the motions of the tongue or of articulation are sometimes alone affected in apoplexy. The seat of this variety of muscular motion has been attempted to be deduced from pathological facts. M. Foville places it in the cornu ammonis and temporal lobe; and M. Bouillaud[2] in the anterior lobe of the brain, in the medullary substance,—the cineritious being concerned, he conceives, in the intellectual part of speech.

It is sufficiently obvious, from the whole of the preceding detail, that the mind must still remain in doubt, regarding the precise part of the encephalon engaged in the functions of muscular motion. The experiments of M. Magendie are, perhaps, more than any others, entitled to consideration. They appear to have been instituted without any particular bias; to subserve no particular theory; and are supported by pathological facts furnished by others. He is, withal, a practised experimenter, and one to whom physiology has been largely indebted. His vivisections have been more numerous, perhaps, than those of any other individual. His investigations, however, on this subject clearly show, that owing to the different morphology of animals, we cannot draw as extensive analogical deductions from comparative anatomy and physiology as might be anticipated. The greater source of discrepancy, indeed, between his experiments and those of MM. Rolando and Flourens, appears to have been the employment of different animals. Where the same animals were the subjects of the vivisections, the results were in accordance. The experiments demand careful repetition, accompanied by watchful and assiduous observation of pathological phenomena; and, until this is effected, we can, perhaps, scarcely feel justified in deducing, from all these experiments and investigations, more than the general propositions regarding the influence of the cerebro-spinal axis on muscular motion, which we have enunciated. It has been already shown, however, that strong evidence may be adduced in favour of the view of M. Flourens, that the cerebellum is the regulator or co-ordinator of the muscular movements,[3] and it is the one now embraced by the generality of physiologists; although it must be admitted, with M. Longet,[4] that "the precise determination of the uses of the cerebellum is one of the most embarrassing problems in physiology."

[1] Adelon, Physiologie de l'Homme, edit. cit., ii. 44.

[2] Magendie's Journal de Physiologie, tom. x.; also, Belhomme, Archiv. Général. de Médecine, Mai, 1845.

[3] Longet, Anatomie et Physiologie du Système Nerveux, i. 703, Paris, 1842.

[4] Traité de Physiologie, ii. 272, Paris, 1850.

The nerves, it has been shown, are the agents for conducting the locomotive influence to the muscles. At one time, it was universally believed, that the same nerve conveys both sensation and volition; but the pathological cases, that not unfrequently occurred, in which either sensation or voluntary motion was lost, without the other being necessarily implicated; and, of late years, the beautiful additions to our knowledge of the spinal nerves, for which we are mainly indebted to Sir Charles Bell,[1] and M. Magendie,[2] have satisfied the most sceptical, that there are separate nerves for the two functions, although they may be enveloped in the same neurilemma or nervous sheath; and may constitute one nervous cord. We have more than once asserted, that the posterior part of the spinal marrow, with the nerves proceeding from it, has been considered to be chiefly concerned in the function of sensibility; and the anterior column, and the nerves connected with it, to be inservient to muscular motion; whilst a third intervening column, in the opinion of Sir Charles Bell, is the source of all the respiratory nerves, and of the various movements connected with respiration and expression. It is proper, here again, to observe, that although these two distinguished physiologists agree in their assignment of function to the anterior and posterior columns of the spinal marrow, Bellingeri[3] has deduced very different inferences from like experiments. He asserts, that having divided on living animals, either the anterior roots of the spinal nerves, and the anterior column of the medulla spinalis—or the posterior roots of these nerves, and the posterior column of the medulla, he did not occasion, in the former case, paralysis of motion, and in the latter, loss of sensation; but only, in the one, the loss of all movements of flexion; and in the other, of those of extension. In his view, the brain and its prolongations,—crura cerebri, corpora pyramidalia, anterior column of the spinal marrow, and the nerves connected with it,—preside over the movements of flexion; and, on the contrary, the cerebellum and its extensions, as the posterior column of the medulla spinalis, and the nerves connected with it, preside over those of extension: he infers, in other words, that there is an *antagonism* between these sets of nerves. The *primâ facie* evidence is against the accuracy of Bellingeri's experiments. The weight of authority in opposition to him is, in the first place, preponderant; and in the second place, it seems highly improbable, that distinct nerves should be employed for the same kind of muscular action. Moreover, in experiments on the frog, Professor Müller established the correctness of the views of Bell. It seems, that the different physiologists, who engaged in the inquiry before he did, employed warm-blooded animals in their experiments, and he imagines, that the pain, resulting from the necessarily extensive wounds, may have had such an effect on the nervous system as to modify, and perhaps even counteract, the results. Müller employed the frog, whose sensibility is less acute, and tenacity

[1] The Nervous System, &c., 3d edit., Lond., 1837, and Narrative of the Discoveries of Sir Charles Bell in the Nervous System, by A. Shaw, London, 1839.

[2] Précis Elémentaire, &c., 2de édit., i. 216.

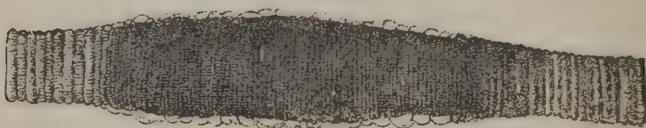
[3] Exper. Physiol. in Med. Spinal. August, Taurin., 1825; Ragionamenti, Sperienze, &c., comprovanti l'Antagonismo Nervoso, &c., Torino, 1833; and an Analysis of the same, in Edinb. Med. and Surg. Journ., Jan., 1835, p. 160.

of life greater. If the spinal marrow of this animal be exposed, and the posterior roots of the nerves of the lower extremities be cut, not the least motion is perceptible when the divided roots are touched by mechanical means, or galvanism. But if the anterior roots be touched, the most active movements are instantly observed. These experiments, Müller[1] remarks, are so readily made, and the evidence they afford is so palpable, that they leave no doubt as to the correctness of the views of Sir Charles Bell.

Experiments, by M. Magendie, and by Dr. Kronenberg,[2] of Moscow, have shown, that a portion of the fibres of the sensitive roots extends to the point of union between them and the anterior roots, and is reflected to the anterior column of the spinal marrow;—the return or reflection of the fibres taking place near the junction of the two roots. This arrangement of the fibres accounts for the fact, often noticed by physiologists, that some degree of sensibility appears to be manifested, in experiments on animals, when the motor roots of the nerves are irritated. The sensibility of the portio dura, a motor nerve, has been long known, and properly ascribed to its receiving filaments of the fifth pair. Motions can be excited by irritating the posterior root, which are owing to its connexion with the spinal cord. This irritation does not act immediately upon the muscles through the trunk of the nerve, which the posterior root contributes to form; but it excites a motor impulse in the spinal cord, which is propagated through the anterior roots to the periphery of the system.

In the ordinary case of the action of a voluntary striped or striated muscle, the nervous influence, emanating from some part of the cerebro-spinal axis, under the guidance of volition, proceeds along the nerves with the rapidity of lightning, and excites the muscle to contraction. The muscle, which was before smooth, becomes rugous; the belly more tumid; the ends approximate, and the whole organ is rendered thicker, firmer, and shorter. The researches of Mr. Bowman[3] have shown, that in the state of contraction the transverse striæ, before described as existing in each fibre, approach each other; whilst its diameter is increased; hence the solid parts are more closely approximated, and the fluid which previously existed between them is pressed out so as to form bullæ in the sarcolemma, as represented in Fig. 353, from Mr. Bowman. The

Fig. 353.



Muscular Fibre of Dytiscus in contraction.

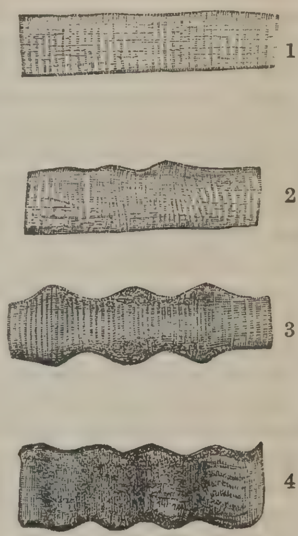
marginal representations, Fig. 354, of the muscular fibre of the skate, at rest and in contraction, are also from Mr. Bowman. It is proper to

[1] Elements of Physiology, by Baly, p. 644, Lond., 1838.
[2] Müller's Archiv., Heft v. 1839.
[3] Art. Muscular Motion, in Cyclop. of Anat. and Physiol., Part xxiv. p. 525, London, July, 1842; and Philosophical Transactions for 1840–1841.

remark, however, that these representations are of muscular fibres when in an unnatural condition,—separated, that is, from the rest of the economy, and it cannot be considered established, that contraction excited by the agency of the nerves is accomplished in precisely the same manner.

With regard to the degree of contraction or shortening, which a muscle experiences, some difference of sentiment has prevailed. Bernouilli and Keill[1] estimated it at one-third of the length; and Dumas[2] carried it still higher. It must, of course, be proportionate to the length of the fibres,—being greater, the longer the fibres. It has, also, been a subject of experiment and speculation, whether the bulk and the specific gravity of a muscle be augmented during contraction. Borelli[3] and Sir Anthony Carlisle[4] affirm, that its bulk is increased. In the experiments of the latter, the arm was immersed in a jar of water, with which a barometrical tube was connected; and when the muscles were made to contract strongly, the level of the water in the tube was raised. Glisson, however, from the same experiment, deduced opposite conclusions; Swammerdam and Ermann[5] appear to be of their opinion; but Sir Gilbert Blane,[6] Mr. Mayo,[7] Barzellotti,[8] MM. Dumas and Prévost,[9] and Valentin,[10] during the most careful experiments, could see no variation in the level of the fluid; and, consequently, do not believe, that the size of a muscle is modified by contraction. Sir Gilbert enclosed a living eel in a glass vessel filled with water, the neck of which was drawn out into a fine tube; he then, by means of a wire introduced into the vessel, irritated the tail of the animal, so as to excite strong contraction, during which he noticed, that the water in the vessel remained stationary. He, likewise, compared the two sides of a fish, one of which had been crimped, and thus brought into a state of strong contraction;—the other left in its natural condition: their specific gravity was the same. The experiment of Barzellotti was the following.

Fig. 354.



Muscular Fibre of Skate.

In a state of rest (1), and in three different stages of contraction (2, 3, 4).

[1] Tentamina-Medico-Physica, Lond., 1718.
[2] Principes de Physiologie, &c., 2de édit., Paris, 1806.
[3] De Motu Animalium, addit. J. Bernouillii, Medit. Mathem. Muscul., L. B. 1710.
[4] Philos. Transact. for 1805, pp. 22, 23. [5] Gilbert's Annalen, p. 40, 1812.
[6] A Lecture on Muscular Motion, &c., Lond., 1778; and Select Dissertations, &c., p. 239.
[7] Anatomical and Physiological Commentaries, i. 12; and Outlines of Human Physiology, 3d edit., p. 35, Lond., 1833.
[8] Esame di alcune moderne Teorie intorno alla Causa prossima della Contrazione moscolare, Siena, 1796.
[9] Op. citat., and Magendie, Pr´cis, &c., i. 222.
[10] Lehrbuch der Physiologie des Menschen, S. 42, Braunschweig, 1844; and Grundriss der Physiologie, S. 218, Braunschweig, 1846.

He suspended, in a glass vessel, the posterior half of a frog; filled the jar with water, and closed it with a stopper traversed by a narrow, graduated tube. The muscle was then made to contract by means of galvanism, but in no case was the level of the liquid in the tube changed. It may, then, be concluded, that the bulk of a muscle is not much, if at all, greater when contracted than when relaxed. Professor E. Weber, who repeated the experiments of Ermann, detected an increase of bulk, but it was exceedingly small.[1]

During contraction, the muscle is sometimes so rigid and elastic as to be capable of vibration when struck. The ordinary firm state is well exhibited by the masseter, when the jaws are forcibly closed; and some men possess the power of producing sonorous vibrations by striking the contracted biceps with a metallic rod.

It has been a matter of dispute whether the quantity of blood circulating in a muscle is diminished during contraction. At one time, it was universally believed, that such diminution existed, and that it accounted for the diminished size of the muscle during contraction. This last allegation we have shown to be inaccurate; and no correct deduction can, consequently, be drawn from it. Sir Anthony Carlisle[2] adopted the opinion, that muscles become pale during contraction; but he offers no proof of it. The probability is, that he implicitly obeyed, in this respect, the dicta of his precursors, without observing the incongruity of such a supposition with his idea, that the absolute size of the muscle is augmented during contraction. The truth is, we have no evidence, that the colour of a muscle, or the quantity of blood circulating in it, is altered during contraction. Bichat,[3] who adopted the opinion, that the blood is forced out during this state, relies chiefly upon the fact, known to every one, that in the operation of blood-letting from the arm the flow of blood is augmented by working the muscles; but the additional quantity expelled is properly ascribed by Dr. Bostock[4] to the compression of the large venous trunks by the swelling out of the bellies of the muscles. The prevalent belief, amongst physiologists of the present day, is, that there is no change of colour in the muscle during contraction.

When the extremities of a muscle are made to approximate, the belly, of course, swells out; and would probably expand to such an extent, that the fasciculi, of which it is composed, would separate from each other, were it not for the areolar membrane and aponeuroses, with which they and the whole muscle are enveloped.

The phenomena attendant upon the relaxation of a muscle are the reverse of those that accompany its contraction. The belly loses its rugous character; becomes soft, and the swelling subsides; the ends recede, and the organ is as it was prior to contraction. It is obvious, however, that after a part, as the arm, has been bent by the contraction of appropriate muscles, simple relaxation would not be sufficient to restore it to its original position; for although the relaxation of a muscle has been regarded by Bichat and others to be, in part at least,

[1] Art. Muskelbewegung, in Wagner's Handwörterbuch der Physiologie, 15te Lieferung, S. 52 und 121, Braunschweig, 1846.

[2] Op. citat., p. 27.

[3] Anat. Général., tom. iii. § 2.

[4] Physiology, 3d edit., p. 94, Lond., 1836.

an active effort; and to consist in something more than the mere cessation of contraction, the evidence in favour of the view is extremely feeble and unsatisfactory. The arrangement of the muscular system is, in this, as in every other respect, admirable, and affords signal evidence of Omnipotent agency. The arm, as in the case selected above, has not only muscles to bend, but also to extend it; and, accordingly, when it has been bent, and it becomes necessary to extend it, the flexor muscles are relaxed and rest, while the extensors are thrown into action. This disposition of antagonist muscles prevails in almost every part of the frame, and will require notice presently.

Muscles are not, however, the sole agents in replacing parts. Many elastic textures exist, which, when put upon the stretch by muscular contraction, have a tendency to return to their former condition, as soon as the extending cause is removed. Of this a good example occurs in the cartilages of prolongation, which unite the ribs to the sternum. During inspiration, these elastic bodies are extended; and, by returning upon themselves, they become active agents of expiration, and tend to restore the chest to its unexpanded state.

The production of the phenomena of muscular contraction is, so far as is known, unlike any physical process with which we are acquainted. It has, therefore, been considered essentially organic and vital; and, like other operations of the kind, will probably ever elude our researches. Yet here, as on every obscure subject, hypotheses have been innumerable; varying according to the fashionable systems of the day, or the views of the propounder. They, who formerly believed that the muscular fibre is hollow, or vesicular, ascribed its contraction to distension by the influx of "animal spirits" or of blood; and relaxation to the withdrawal of those. Such were the hypotheses of Borelli,[1] Stuart,[2] and others. Independently, however, of the objection to these views, that we have no positive evidence of the existence of such vesicles, it is obvious, that the explanation is defective, inasmuch as we have still to look to the cause that produces this mechanical influence. Again, how are we to account, under this hypothesis, for the surprising efforts of strength executed by muscles? The mechanical influence of animal or other spirits—granting for a moment their existence—might develope a certain degree of force; but how can we conceive them able, as in the case of the muscles inserted into the foot, to develope such a force as to project the body from the ground? In all these cases, a new force is generated in the brain; and this, by acting on the muscular fibre, is the efficient cause of the contraction. Moreover, what an inconceivable amount of fluids would be necessary to produce the contraction of the various muscles, that are constantly in action; and what, it has been asked, becomes of these fluids when relaxation succeeds to contraction? Some have affirmed, that they are absorbed by the venous radicles; others, that they run off by the tendons; and others, again, that they become neutralized in the muscle, and communicate to it the greater size it attains under exercise. These fantasies are too abortive to require comment.

[1] De Motu Animalium, Lugd. Bat., 1710.
[2] De Structurâ et Motu Musculari, Lond., 1738.

When chemical hypotheses were in fashion in medicine, physiology participated in them largely. At one time it was imagined, that an effervescence was excited in the muscle by the union of two substances, one of which was of an acid, the other of an alkaline nature. Willis, Mayow, Keill,[1] Bellini,[2] &c., supported opinions of this kind; some ascribing the effervescence to a union of the nervous fluid with the arterial blood; others to a union of the particles of the muscular fibre with the nervous fluid; and others, to the disengagement of an elastic gas, primitively contained in the blood, and separated from it by the nervous spirits. It would, however, be unprofitable, as well as uninteresting, to repeat the different absurdities of this period—so prolific in physical obscurities. Medicine has generally kept pace with physics, and where the latter science has been dark and enigmatical, the former has been so likewise. In physiology, this is especially apparent; most of the natural philosophers of eminence having applied their doctrines in physics to the explanation of the different functions of the human frame. Newton, Leibnitz, and Des Cartes, were all speculative physiologists. The discovery of electricity gave occasion to its application to the topic in question; and it was imagined, that the fibres of the muscle might be disposed in such a manner as to form a kind of battery, capable of producing contraction by its explosions; and after the discovery of galvanic electricity, Valli[3] attempted to explain muscular contraction, by supposing that the muscles have an arrangement similar to that of the galvanic pile. Haller[4] endeavoured to resolve the problem by his celebrated doctrine of *irritability*, which will engage attention hereafter. He conceived, that the muscles possess, what he calls, a *vis insita;* and that their contraction is owing to the action of this force, excited by a stimulus, which stimulus is the nervous influx directed by volition. This, although a true doctrine we think, sheds no new light on the mysterious process. It is, in fact, cutting the Gordian knot. We should still have to explain the precise mode of action of the vis insita:[5] but that it is not in any way derived from the nervous system will be shown when treating of LIFE.

The hypothesis of Prochaska[6] is entirely futile. He gratuitously presumes, that minute ramifications of arteries are every where connected with the ultimate muscular filaments, twining around them, and crossing them in all directions. When these vessels are rendered turgid by an influx of blood,—by passing among the filaments, they must, he conceives, bend the latter into a serpentine shape, and thus diminish their length, and that of the muscle likewise. Sir Gilbert Blane,[7] again, throws out a conjecture,—deduced from experiments, in which he found that the actual bulk of a muscle is not changed during contraction, but that it gains in thickness exactly what it loses in length,—that this may be owing to the muscle being composed of

[1] Tentamin. Medico-Physic., No. v., Lond., 1718. [2] Bostock, op. cit., p. 111.
[3] Experiments in Animal Electricity, Lond., 1793.
[4] Element. Physiol., xi. 214; and Oper. Minor., tom. i.
[5] M. Hall, art. Irritability, Cyclop. of Anat. and Physiol., July, 1840.
[6] De Carne Musculari, § ii., Vienn., 1778.
[7] Op. citat.

particles of an oblong shape; and that when the muscle is contracted, the long diameter of the particle is removed from a perpendicular to a transverse direction. But the same objection applies to this as to other hypotheses on the subject; that it is entirely gratuitous,—resting on no histological observation whatever.

Two views have been, perhaps, the most prevalent; one which considers muscular contraction to be a kind of combustion; another that it is produced by electricity. The former, which was originally propounded by Girtanner,[1] and zealously embraced by Dr. Beddoes, who was more celebrated for his enthusiasm than for the solidity of his opinions, has now few supporters. This hypothesis supposes, that muscular contraction depends upon the combustion of the combustible elements of the muscle, hydrogen and carbon, by the oxygen of the arterial blood; the combustion being produced by the nervous influx, which acts in the manner of an electric spark;—at least, such is the view adopted by M. Richerand,[2] one of the most fanciful of physiological speculators. Of course, we have neither direct nor analogical evidence of any such combustion, which, if it existed at all, ought to be sufficient, in a short space of time, to entirely consume the organs that furnish the elements. The idea is as unfounded as numerous others that have been entertained, and is worthy only of particular notice, from its being professed in one of the well-known works on physiological science.

The second hypothesis refers muscular contraction to electricity. Attention has been already directed to the electroid or galvanoid character of the nervous agency; and we have some striking examples on record of the analogous effects produced by the physical and the vital fluid on the phenomena under consideration. It has been long known, that when nerves and muscles are exposed in a living animal, and brought into contact, contractions or convulsions occur in the latter. Galvani[3] was the first to point this out. He decapitated a living frog; removed the fore-paws, and quickly skinned it. The spine was divided, so as to leave the spinal marrow communicating only with the hinder extremities by means of the lumbar nerves. He then took, in one hand, one of the thighs of the animal, and the vertebral column in the other, and bent the limb until the crural muscles touched the lumbar nerves. At the moment of contact the muscles were strongly convulsed. The experiment was repeated by Volta,[4] Aldini,[5] Pfaff,[6] Humboldt,[7] and others; and with like results. Aldini caused convulsions in the muscles by the contact of those organs with nerves, not only in the same frog, but in two different frogs. He adds, that he remarked them when he put the nerves of a frog in connexion with the muscular flesh of an ox recently killed.[8] Humboldt made numerous experiments of this kind on frogs, and found convulsions supervene when he placed

[1] Journ. de Physique, xxxvii. 139. [2] Elements of Physiology, § 163.

[3] Mem. sull' Elettricita Animale, Bologn., 1797.

[4] Memoria sull' Elettricita Animale, 1782.

[5] Essai Théoretique et Expériment. sur le Galvanisme, Paris, 1804.

[6] Ueber thierische Electricität und Reizbarkeit, Leipz., 1795.

[7] Versuche über die gereizte Muskel und Nervenfaser, Posen und Berlin, 1797.

[8] Traité complet de Physiologie de l'Homme, par Tiedemann, traduit par Jourdan, p. 559, Paris, 1837.

upon a dry plate of glass a posterior extremity whose crural nerves had been exposed, and touched the nerves and muscles with a piece of raw muscular flesh, insulated at the extremity of a stick of sealing-wax. Convulsions likewise occurred, when, instead of one piece of flesh, he used three different pieces to form the chain, one of which touched the nerve; the other the thigh, and the third the two others. The experiments were repeated by Ritter with similar results; but they were only found to succeed, when the frogs were in full vital activity,—especially in spring, after pairing; when the animal was of sufficient size, and its preparation for the experiment had been rapidly effected.

From all these experiments it might be inferred, that parts of an animal may form galvanic chains, and produce a galvanic effect, which, independently of any mechanical excitation, may give rise to the contraction of muscles. This excitation of electricity in chains of animal parts, M. Tiedemann thinks, ought not to be esteemed a vital act. Its effects only—the contractions excited in the muscles—are dependent on the vital condition of the muscles and nerves. He considers, that electricity, excited in chains of heterogeneous animal parts, may be modified and augmented by the organic or living forces; and that, moreover, in certain animals, organs exist, the arrangement of which is such as to excite electricity during their vital action as in the different kinds of electrical fishes; but in some experiments, instituted by M. Edwards,[1] the effects above referred to were produced by touching a denuded nerve with a slender rod of silver, copper, zinc, lead, iron, gold, tin, or platinum, and drawing it along the nerve for the space of from a quarter to a third of an inch. He took care to employ metals of the greatest purity, as they were furnished him by the assayers of the mint. But it was not even necessary that the rod should be metallic: he succeeded with glass or horn. All metals, however, did not produce equally vigorous contractions. Iron and zinc were far less effective than the others; but no accurate scale could be formed of their respective powers.

Much difference is found to exist, when electricity is employed, according as the nerve is insulated or not; for as the muscular fibre is a good conductor of electricity, if the nerve be not insulated, the electricity is communicated to both nerve and muscle, and its effect is consequently diminished. It became, therefore, interesting to M. Edwards to discover, whether any difference would be observable, when one metal only was used, whether the nerve was insulated or not. In the experiments above referred to, the nerve was insulated by passing a strip of oiled silk beneath it. A comparison was now instituted between an animal thus prepared, and another whose nerves instead of being insulated, rested on the subjacent flesh. He made use of small rods, with which he easily excited contractions when he drew them from above to below along the denuded portion of nerve that was supported by the oiled silk; but he was unable to cause them when he passed the rod along the nerve of the other animal which was not insulated. His experiments were then made on two nerves of the same

[1] Appendix to Edwards on the Influence of Physical Agents on Life,—Hodgkin and Fisher's translation, Lond., 1832.

animal; and he found that after having vainly attempted to produce contractions by the contact of a nerve resting upon muscle, they could still be induced if the oiled silk were had recourse to; and he was able to command their alternate appearance and disappearance by using a non-conductor or a conductor for the support of the nerve. Somewhat surprised at these results, M. Edwards was stimulated to the investigation,—whether some degree of contraction might not be excited by touching the uninsulated nerve; and having remarked, that contractions were most constantly produced in the insulated nerve by a quick and light touch, he adopted this method on an animal whose nerve was not insulated, and frequently obtained slight contractions. All his experiments on this subject seemed to prove, that, *cæteris paribus*, muscular contractions, produced by the contact of a solid body with a nerve, are much less considerable, or even wholly wanting, when the nerve, in place of being insulated, is in communication with a good conductor; and it would seem to follow, as a legitimate conclusion, that these contractions are dependent on electricity; facts, which it is well to bear in mind, in all experiments on animals where feeble electrical influences are employed.[1]

Galvanic electricity, it will be seen hereafter, is one of the great tests of muscular irritability, and is capable of occasioning contractions for some time after the death of the animal, as well as of maintaining, for a time, many of the phenomena peculiar to life. This is the reason why muscular contraction, excited by this nervous, electroid fluid, has been regarded as an electrical phenomenon. Much discrepancy has, however, arisen amongst the partisans of this opinion regarding its *modus operandi*. Rolando, we have seen, assimilates the cerebellum to an electro-motive apparatus, which furnishes the fluid that excites the muscles to contraction. Some have compared the spinal column to a voltaic pile, and have supposed the contraction of a muscle to be owing to an electric or galvanic shock. The views of MM. Dumas and Prévost[2] are amongst the most striking. By a microscope, magnifying ten or twelve diameters, they first of all examined the manner in which the nerves are arranged in a muscle; and found, as has been already observed, that their ramifications always enter the muscle in a direction perpendicular to its fibres. They satisfied themselves, that none of the nerves really terminate in the muscle; but that the final ramifications embrace the fibres like a noose, and return to the trunk that furnishes them, or to one in its vicinity,—the nerve setting out from the anterior column of the spinal marrow, and returning to the posterior. On farther examining the muscles at the time of their contraction, the parallel fibres composing them were found, under the microscope, to bend in a zigzag manner, and to exhibit a number of regular undulations; such flexions forming angles, which varied according to the degree of contraction, but were never under fifty degrees. The flexions, too, always occurred at the same parts of the fibre, and to them the shortening of the muscle was owing, as MM. Dumas and Prévost proved by calculat-

[1] Coldstream, art. Animal Electricity, in Cyclop. Anat. and Physiol., P. ix., p. 93, Jan., 1837; and J. Müller, Elements of Physiology, by Baly, p. 261, London, 1838.

[2] Journal de Physiologie, tom. iii. 301; and Magendie, Précis, i. 220.

ing the angles. The angular points were always found to correspond to the parts where the small nervous filaments enter or pass from the muscles. They therefore believed, that these filaments, by their approximation, induce contraction of the muscular fibre; and this approximation they ascribed to a galvanic current running through them; which, as the fibres are parallel and in proximity, they thought, ought to cause them to attract each other, according to the law laid down by M. Ampère, that two currents attract each other when they move in the same direction. The living muscles are, consequently, regarded by them as galvanometers, and galvanometers of an extremely sensible kind, on account of the very minute distance and tenuity of the nervous filaments. They moreover affirm, that, by anatomical arrangement, the nerve is fixed in the muscle in the very position required for the proper performance of its function; and they esteem the fatty matter, which envelopes the nervous fibres, and which was discovered by M. Vauquelin, as a means of insulation for preventing the electric fluid from passing from one fibre to another.

Soon after hearing of M. Ampère's discovery of the attraction of electrical currents, it occurred to Dr. Roget,[1] that it might be possible to render the attraction between the successive and parallel turns of heliacal or spiral wires very sensible, if the wires were sufficiently flexible and elastic; and, with the assistance of Dr. Faraday, his conjecture was put to the test of experiment in the laboratory of the Royal Institution of London. A slender harpsichord-wire, bent into a helix, being placed in the voltaic circuit, instantly shortened itself whenever the electric stream was sent through it; but recovered its former dimensions the moment the current was intermitted. From this experiment it was supposed, that possibly some analogy might hereafter be found to exist between the phenomenon and the contraction of muscular fibre.

The views of MM. Dumas and Prévost were altogether denied by M. Raspail,[2] on the ground, that it is impossible to distinguish, by the best microscope, the ultimate muscular fibre from the small nervous fibrils by which those gentlemen consider them to be surrounded loopwise. He farther affirmed, that the zigzag form is the necessary result of the method in which they performed their experiments, and is produced by the muscular fibre adhering to the glass on which it was placed. His own idea, founded on numerous observations, is, that the contraction of the fibre in length is always occasioned by its extension in breadth under the influence of the vital principle. Independently, however, of M. Raspail's objection, the circumstance, that, in this mode of viewing the subject, the muscle itself is passive, and the nerve alone active, is a stumbling-block in the way of the views of MM. Dumas and Prévost, and of Dr. Roget. It is proper, too, to remark, that M. Person[3] was unable to detect any longitudinal galvanic currents in the nerves by the most sensible galvanometer; and that other stimuli besides galvanism are capable of exciting the muscular fibre to contraction. This we

[1] Electro-Magnetism, p. 59, in 2d vol. of Nat. Philosophy, Library of Useful Knowledge, London, 1832.

[2] Chimie Organique, p. 212, Paris, 1833.

[3] Journal de Physiologie, tom. x., Paris, 1830.

see daily in experiments on the frog, by dropping salt on the denuded muscle. Prof. Müller[1] hence infers, that a nerve of motion, during life, and whilst its excitability or irritability continues, is so circumstanced, that whatever suddenly changes the relative condition of its molecules excites a contraction at the remote end of the muscle, and that electrical, chemical, and mechanical irritants are, in this respect, similarly situate.

Interesting electro-physiological researches have been made by Professor Matteucci of Pisa, from which he has deduced the following results. *First.* Muscle is a better conductor of electricity than nerve; and nerve conducts better than brain. The conducting power of muscle may be taken as four times greater than that of brain or nerve. *Secondly.* In the muscles of living animals, as well as of those recently killed, an electric current exists, which is directed from the interior of each muscle to its surface. The duration of this muscular current corresponds with that of contractility; in cold-blooded animals, therefore, it is greatest: in mammalia and birds very brief. Temperature has a considerable influence on the intensity of the current,—a small amount of electricity being developed in a cold medium; a larger one when the medium is moderately warm. Any circumstance that enfeebles the frogs (the animals experimented on) and deranges their general nutrition, diminishes the power of the muscles to generate electricity, as it likewise impairs the contractile force. The muscular current appears to be quite independent of the nervous system. It is uninfluenced by narcotic poisons in moderate doses, but is destroyed by large doses, such as would kill the animal. The developement of this muscular current seems evidently to depend on the chemical action constantly taking place as an effect of the changes accompanying nutrition. *Thirdly.* In frogs an electric current exists which is distinct from the muscular current. It proceeds from the feet to the head, and is peculiar to batrachian reptiles. *Fourthly.* Singular results are obtained by applying electricity in various ways to nerves. On making experiments on the sciatic nerves of rabbits, he found that on closing the circuit of the direct electric current, or the current passing from the brain to the nerves, contractions in the muscles of the posterior limbs were produced; whilst opening this circuit was followed by marked signs of pain, with contraction of the muscles of the back, and feeble contractions of the posterior limbs. On closing the circuit of the inverse current, or that directed from the nerves to the brain, signs of pain, contractions of the muscles of the back, and feeble contractions of the posterior limbs were produced. On opening it, contractions of the posterior limbs followed.[2]

Similar electro-physiological researches have been made by M. Dubois-Reymond in regard to the electric current, which accord with many of the results obtained by M. Matteucci. On comparing differ-

[1] Art. Electricität (thierische), in Encyclopäd. Wörterb. der Medicin. Wissensch., x. 545, Berlin, 1834.

[2] For an account of Matteucci's researches, see Todd and Bowman, Physiological Anatomy and Physiology of Man, vol. i., Lond., 1845, and, especially, Matteucci, Lectures on the Physical Phenomena of Living Beings, by Pereira, Amer. edit., pp. 176 and 224, Philad., 1848.

ent muscles with each other, he observed that the current was more intense when the muscle had to execute a greater mechanical action, voluntary or involuntary. The muscular fasciculi of the heart, for example, which are not under the influence of the will, exhibited as energetic a current as the muscles of animal life, which are all voluntary; whilst the muscular fasciculi of the intestines, which have only feeble mechanical actions to execute, exhibited a very weak current. He found, however, contrary to Matteucci, that during muscular contraction there was a remarkable diminution in the natural current.

The numerous experiments which have been made by different observers have as yet, led to no definite physical or physiological conclusions. This is sufficiently shown by the *resumé* of M. Pouillet, who reported to the French Institute on the researches of M Dubois-Reymond. The cause, he concludes, of these organic currents is unknown:—it is probable that they do not result from any external chemical action, and it is not demonstrated, that they are induced by any internal. "It is a question to be solved; and, according as it may receive a positive or a negative solution, the ulterior consequences will assume very different characters."[1] M. Dubois-Reymond found, that an electric current exists in nerves, which in its manifestations greatly resembles the muscular current.

With regard to the hypotheses which ascribe muscular contractility to the chemical composition of the fibre, and that which maintains, that the property is dependent upon the mechanical structure of the fibre, they are undeserving of citation, notwithstanding the respectability of the individuals who have written and experimented on the subject. They merely seem to show, that here, as in every case, a certain chemical and mechanical constitution is necessary, in order that the vital operations, peculiar to the part, may be accomplished.

But not only is it necessary, that the muscle shall possess a proper physical organization, it must, likewise, be endowed with a property essentially vital; in other words, with *irritability* or *contractility*. The cause of the ordinary contraction of muscles is, doubtless, the nervous influx; but if we materially alter the condition of the muscle, although the nervous influx may be properly transmitted to it, there will be no contraction. This applies to the living animal; but not apparently to the dead; for Valentin[2] found, that after trying the femoral artery or vein, or dividing the sciatic nerve in frogs, the full strength of the muscle remained unaltered for several days,—in one case for twelve. We moreover find, that after a muscle has acted for some time, it becomes fatigued, notwithstanding volition may regularly direct the nervous influx to it; and that it requires repose, before it is again capable of executing its functions.

In the upper classes of animals, contractility remains for some time after dissolution; in the lower, especially in the amphibia, the period

[1] Béraud, Manuel de Physiologie de l'Homme, p. 36, Paris, 1853. Ludwig, Lehrbuch der Physiologie des Menschen, 1er Bd., S. 316, Heidelb., 1853. See, on all this subject, Béclard, Traité Élémentaire de Physiologie Humaine, p. 486, Paris, 1855, and Carpenter, Principles of Human Physiology, Amer. edit., by Dr. F. G. Smith, p. 434, Philad., 1855.

[2] Lehrbuch der Physiologie des Menschen, ii. 176–92, Braunschweig, 1844.

during which it is evinced on the application of appropriate stimuli is much greater. From experiments on the bodies of executed criminals, M. Nysten found that irritability ceased in the following order of parts. The left ventricle of the heart first; the intestinal canal at the end of forty-five or fifty-five minutes; the urinary bladder at nearly the same time; the right ventricle after the lapse of an hour; the œsophagus at the end of an hour and a half; the iris a quarter of an hour later; the muscles of animal life somewhat later; and lastly, the auricles of the heart, especially the right, which, in one instance, under the influence of galvanism, contracted sixteen and a half hours after death. These results are singular; and the experiments merit repetition. It is, indeed, strange, that muscles of organic life, apparently circumstanced so much alike, should vary so greatly in the length of time during which they retain their irritability.

One of the most interesting of the many experiments that have been made on the bodies of criminals recently deceased, for the purpose of exhibiting the effects of galvanism or muscular irritability, is detailed by Dr. Ure.[1] The subject was a murderer, named Clydesdale; a middle-sized athletic man, about thirty years of age. He was suspended from the gallows nearly an hour, and made no convulsive struggle after he dropped. He was taken to the theatre of the Glasgow University about ten minutes after he was cut down. His face had a perfectly natural aspect, being neither livid nor tumefied; and there was no dislocation of the neck. In the first experiment, a large incision was made into the nape of the neck, close below the occiput, and the spinal marrow was brought into view. A considerable incision was made, at the same time, into the left hip, through the glutæus maximus muscle, so as to expose the sciatic nerve;[2] and a small cut was made in the heel; from neither of which any blood flowed. A pointed rod, connected with one end of a galvanic battery, of two hundred and seventy pairs of four-inch plates, was now placed in contact with the spinal marrow, whilst another rod, connected with the other end, was applied to the sciatic nerve. Every muscle of the body was immediately agitated with convulsive movements, resembling a violent shuddering from cold. The left side was most powerfully convulsed at each renewal of the electric contact. On removing the second rod from the hip to the heel, the knee being previously bent, the leg was thrown out with such violence as nearly to overturn one of the assistants, who in vain attempted to prevent its extension.

In the next experiment, the left phrenic nerve was exposed at the outer edge of the sterno-thyroideus muscle. As this nerve is distributed to the diaphragm, and communicates with the heart through the

[1] Art. Galvanism, in Dict. of Chemistry, Hare and Bache's Amer. edit., Philad., 1821.

[2] It is not indispensable, in these experiments, to expose the nerve. The author has long known, that, in the case of the frog, it is needless; and, in his experiments, he has been in the habit of acting under this knowledge. The experiments made on three criminals,—two of whom were executed at Philadelphia, and the third at Lancaster, Pennsylvania—showed, indeed, that the effect was even greater when the nerves were not exposed. It was found, too, to be more marked when the current was transmitted from the peripheral extremity of a nerve towards its centre. See Bell's Select Medical Library, for Oct., 1839; Amer. Journ. of Med. Sciences, May, 1840, p. 13; and Medical Examiner, Jan. 23d and 30th, 1841.

pneumogastric nerves, it was expected that, by transmitting the galvanic fluid along it, the respiratory process might be renewed. Accordingly, a small incision having been made under the cartilage of the seventh rib, the point of one rod was brought into contact with the great head of the diaphragm, whilst that of the other was applied to the phrenic nerve in the neck. The diaphragm, which is a main agent in respiration, was instantly contracted, but with less force than was expected. "Satisfied," says Dr. Ure, "from ample experience on the living body, that more powerful effects can be produced in galvanic excitation by leaving the extreme communicating rods in close contact with the parts to be operated on, while the electric chain or circuit is completed by running the end of the wires along the top of the plates in the last trough of either pole, the other wire being steadily immersed in the last cell of the opposite pole, I had immediate recourse to this method. The success of it was truly wonderful. Full, nay laborious breathing instantly commenced. The chest heaved and fell; the belly was protruded and again collapsed, with the relaxing and retiring diaphragm. This process was continued, without interruption, as long as I continued the electric discharges. In the judgment of many scientific gentlemen who witnessed the scene, this respiratory experiment was perhaps the most striking ever made with a philosophical apparatus. Let it also be remembered, that for full half an hour before this period, the body had been well-nigh drained of its blood, and the spinal marrow severely lacerated. No pulsation could be perceived, meanwhile, at the heart or wrist; but it may be supposed that but for the evacuation of the blood,—the essential stimulus of that organ,—this phenomenon might also have occurred."

In a third experiment, the supra-orbital nerve was laid bare in the forehead. The one conducting rod being applied to it, and the other to the heel, most extraordinary grimaces were exhibited. Every muscle in the face was simultaneously thrown into fearful action. "Rage, horror, despair, anguish, and ghastly smiles, united their hideous expression in the murderer's face, surpassing far the wildest representation of a Fuseli or of a Kean." At this period, several of the spectators were forced to leave the room from terror or sickness; and one gentleman fainted.

The last experiment consisted in transmitting the electric power from the spinal marrow to the ulnar nerve as it passes by the internal condyle at the elbow; when the fingers moved nimbly, like those of a violin performer; and an assistant who tried to close the fist, found the hand open forcibly in spite of every effort to prevent it. When one rod was applied to a slight incision in the tip of the forefinger, the fist being previously clenched, the finger was instantly extended; and from the convulsive agitation of the arm, he seemed to point to the different spectators, some of whom thought he had come to life.

The experiments of Dr. Ure have been several times repeated in this country on the bodies of criminals, and with analogous results.[1]

What important reflections are suggested by the perusal of such

[1] Dunbar, in Baltimore Med. and Surg. Journal, i. 245, Balt., 1833, and the Journals referred to in the preceding pages.

cases! The great resemblance between the galvanic and the nervous fluids, and the absorbing idea, to the philanthropist, that galvanism might be found successful in resuscitating the apparently dead, in cases where other means may have failed! Unfortunately, it can rarely happen, that the means will be at hand, so as to be available; and, moreover, when the heart has ceased to beat for a few minutes, it is generally impracticable to cause it to resume its functions.

An experiment, described by Dr. George Fordyce,[1] exhibits the power of contractility resident in the tissues. He slightly scratched, with a needle, the inside of a heart removed from the body, when it contracted so strongly as to force the point of the needle deep into its substance. This experiment has been often cited for the purpose of showing, that the mechanical effect, in such cases, is infinitely greater than the mechanical cause producing it; and hence, as we have endeavoured already to show, that all mechanical explanations must be insufficient to account for the phenomena of muscular contraction. We are compelled, indeed, to infer, that a new force must always be generated.

In the year 1806, a cause was tried before the Court of Exchequer in England, in which a better knowledge of the properties of muscle might have led to a different result.[2] According to the English law, where a man marries a woman seised of an estate of inheritance, and has, by her, issue born alive, which was capable of inheriting her estate,—in such case he shall, on the death of his wife, hold the lands for his life as *tenant by the courtesy* of England. It has, consequently, been a point of moment for the husband to show, that the child was born *alive;* and the law authorities have, with singular infelicity, attempted to define what shall be regarded evidences of this condition. According to Blackstone,[3] "it must be born alive. Some have had a notion that it must be heard to cry, but that is a mistake. Crying, indeed, is the strongest evidence of its being born alive, but it is not the *only* evidence." According to Coke,[4] "if it be born alive it is sufficient, though it be not heard to cry, for peradventure it may be born dumb.[5] It must be proved that the issue was alive; for *mortuus exitus non est exitus;* so that the crying is but a proof that the child was born alive; and so is motion, stirring, and the like." This latitudinarian definition has given occasion to erroneous decisions, as in the trial alluded to, in which the jury agreed that the child was born alive; because, although, when immersed in a warm bath immediately after birth, it did not "cry, or move, or show any symptoms of life;" yet, according to the testimony of two females,—the nurse and the cook,—there twice appeared a twitching and tremulous motion of the lips; and this was sufficient to make it fall under Lord Coke's definition. It is manifest, that, granting such motion to have actually occurred, it

[1] Philos. Transact. for 1788, p. 25.
[2] Taylor, Medical Jurisprudence, Amer. edit., by R. E. Griffith, p. 480, Philad., 1845.
[3] Commentaries, B. ii. 127.
[4] Institutes, 30, a.
[5] It need scarcely be said that the deaf-dumb cry at the moment of birth the same as other children. The natural cry is effected by them as well as by the infant that possesses all its senses. It is the *acquired* voice, alone, which they are incapable of attaining.

was of itself totally insufficient to establish the existence of somatic life. We have seen, that on the application of stimuli, the muscles of a body may be thrown into contraction for *two hours* after the cessation of respiration and circulation or after somatic death. Instead, therefore, of referring the irritability to the existence, at the time, of somatic life, it must be regarded simply as an evidence of the persistence of molecular life in parts that had previously and recently formed part of a living whole.

The contraction of a muscle is followed by its *relaxation;*—the fibres returning to their former condition. This appears to be a passive state; and to result from the suppression of the nervous influx by the will;—in other words, from the simple cessation of contraction. Some have, however, regarded both states to be active, but without proof. Barthez[1] maintains, that the relaxation of a muscle is produced by a nervous action the reverse of that which occasions its contraction;—the will relaxing the muscles as well as contracting them. The muscle is the only part susceptible of contraction. The tendon conveys the force developed by it, passively, to the lever, which has to be moved.

It has been ascertained by MM. Becquerel and Breschet,[2] that a muscle during contraction augments in temperature. This increase is usually more than one degree of Fahrenheit; but at times when the exertion has been continued for five minutes,—as in the case of the biceps of the arm, in sawing wood,—it has been double that amount.[3]

Lastly, a sensation instructs the mind that a muscle has contracted, and this has given rise to the notion of a *muscular sense*, and a *sensation of motion:*—Muskelsinn, Bewegungssinn or *muscular sense* of Gruithuisen, Lenhossek,[4] Brown,[5] Sir C. Bell,[6] and other writers. It appears to be an internal sensation, produced by the muscle pressing on the sensible parts surrounding it, which convey the sensation to the brain. It is by this muscular sense that the brain learns to adapt the effort to the effect to be produced. Without it no precision could exist in the movements of the muscles, and every manual effort—whether of the artist or the mechanic—would be confused and disorderly. The step, too, would be unsteady and insecure. "In chewing our food," says Dr. A. Combe,[7] "in turning the eyes towards an object looked at, in raising the hand to the mouth, and, in fact, in every variety of muscular movement which we perform, we are guided by the muscular sense in proportioning the effect to the resistance to be overcome; and where this harmony is destroyed by disease, the extent of the service rendered us becomes more apparent. The shake of the arm and hand which we see in drunkards, and their consequent incapability of carrying the morsel directly to the mouth, are examples of what would be of daily occurrence, unless we were directed and assisted

[1] Nouveaux Élémens de la Science de l'Homme, Paris, 1806.

[2] Archiv. du Muséum, tom. i. p. 402, and Annales des Sciences Naturelles, nouv. série, iii. 272.

[3] See on this subject Helmholtz, in Müller's Archiv., H. ii. S. 144, Berlin, 1848.

[4] Rudolphi, Grundriss der Physiologie, 2ter Band, 1ste Abtheil, S. 318, Berlin, 1823.

[5] Lectures on Moral Philosophy.

[6] The Hand, &c., Amer. edit., p. 145, Philad., 1833.

[7] Principles of Physiology, 5th edit., p. 131, Edinb., 1836.

by a muscular sense." It enables us to form ideas of force and resistance, by conveying to our minds a distinct idea of the effort required.

The *force* or *intensity of muscular contraction* is dependent upon two causes,—the physical condition of the muscle, and the energy of the brain. A muscle, which is composed of large, firm fibres, will contract,—the energy of the brain being equal,—more forcibly than one with delicate, loose fibres. Volition generally determines the degree of power developed by the voluntary motions; and is accurately regulated so as to raise a weight of one pound or one hundred. We notice astonishing efforts of strength in those that are labouring, at the time, under strong cerebral excitement; mania, rage, delirium, &c. In such cases, the delicate muscles of the female are capable of contracting with a force far transcending that of the healthy male. The power of muscular contraction is, therefore, in a compound ratio with the strength of the organization of the muscle, and the degree of excitation of the brain. When both are considerable, the feats of strength surpass belief; and where both are small, the results are insignificant. The extensors of the knee and foot occasionally contract with so much violence as to fracture the patella and tendo Achillis, respectively. The force, developed in the calf of the leg, must be great, when a person stands on tiptoe with a burden on his head or shoulders; or when he projects his body from the soil, as in leaping. Rudolphi[1] asserts, that he has seen a horse, which fractured its under-jaw by biting a piece of iron.

It has been a question, whether the power of a muscle is greater or less at different degrees of contraction, the same stimulus being applied. To determine this, Schwann[2] invented an apparatus, which should accurately measure the length of the muscle, and the weight it would balance by its contraction; and from his experiments it appeared, that a uniform increase of force is attended with a nearly uniform increase in the length of the muscle. The explanation of this by Dr. Carpenter[3] is probably correct;—that, as the observations of Mr. Bowman have clearly shown, there must be a considerable displacement of the constituents of every fibre during contraction, it is easy to understand, that the greater the contraction the more difficult must any farther contraction become. "If, between a magnet and a piece of iron attracted by it, there were interposed a spongy elastic tissue, the iron would cease to approach the magnet at a point, at which the attraction of the magnet would be balanced by the force needed to compress still farther the intermediate substance."

We have a number of feats of surprising strength on record, several of which have been collected by Sir David Brewster.[4] Of these, the cases of John Charles Van Eckeberg, who travelled through Europe under the appellation of Samson, and of Thomas Topham, are the most authentic and extraordinary. Dr. Desaguliers saw Topham, by the strength of his fingers, roll up a very strong and large pewter dish. He broke seven or eight short and strong pieces of tobacco pipe with the force of his middle finger, having laid them on his first and third

[1] Op. cit., p. 303. [2] J. Müller, Physiology, p. 903.

[3] Human Physiology, § 394, Lond., 1842.

[4] Letters on Natural Magic, Amer. edit., p. 222, New York, 1832.

fingers. Having thrust under his garter the bowl of a strong tobacco-pipe, his leg being bent, he broke it to pieces by the tendons of his hams without altering the flexure of his knee. He broke another such bowl between his first and second fingers, by pressing his fingers together sideways. He lifted a table six feet long—which had half a hundred weight hanging at the end of it—with his teeth, and held it in a horizontal position for a considerable time, the feet of the table resting against his knees. He took an iron kitchen poker, about a yard long, and three inches in circumference, and, holding it in his right hand, he struck upon his bare left arm, between the elbow and wrist, till he bent the poker nearly to a right angle. He took such another poker, and holding the ends of it in his hands, and the middle against the back of his neck, he brought both ends of it together before him; and afterwards pulled it nearly straight again. He broke a rope about two inches in circumference, which was in part wound about a cylinder of four inches in diameter, having fastened the other end of it to straps that went over his shoulders. Lastly, he lifted a rolling-stone, eight hundred pounds in weight, with his hands only, standing in a frame above it, and taking hold of a chain that was fastened to it.

An equally remarkable example is given by a recent well-known traveller[1] as having been witnessed by him in Paris. In the Place du Carrousel, a large coarse French woman made the following exhibition, in the presence of a great crowd of spectators. A rough block of stone, weighing more than three hundred pounds, and which two men could barely lift from the ground, was fastened round with several turns of rope. The long black hair of the woman, which was divided into seven traces, tightly platted and fastened at the end, was then brought down, and attached to these ropes, whilst the woman herself bent her head back towards the stone for the purpose of admitting of the traces being fastened. When this was done, she slowly rose to her erect position, lifting the stone entirely from the ground, its weight being borne by the seven traces of her hair, and the pressure resting wholly on her scalp. She then began to turn herself slowly round, swinging the stone just fastened to her hair, until, by the progressively increasing motion, she twirled round as rapidly as the spinning dervishes, or an opera dancer in a pirouette, but for a longer period,—the stone all this while going out farther and farther from her person till it swung round almost horizontally, and with a velocity that made it fearful to look upon, relaxing gradually from the highest point of motion till it rested at her feet. It was then loosened from the hair and the cords; and her next feat was to place two rush-bottomed chairs at a distance of about four feet and a half from each other, when she placed her head on one, and her heels on the other, thus lying horizontally between the two, without any support for her back or loins in the centre, and neither her head nor her heels being more than six inches from the outer edge of the chairs. Whilst in this condition, two men were invited to come from the crowd and lift up the stone, so as to place it on her stomach. Two persons came from amongst the bystanders, and one of them not being a strong man, they were unable to lift it, when

[1] J. S. Buckingham, Travels in France, Piedmont, &c., ii. 63, Lond., 1849.

a third came to their assistance; but not till after at least twenty persons had tried to lift the stone a little from the ground, to be assured it was not hollow, and that there was no deception, and each had failed to lift it half an inch from where it stood. The three men, however, raised it up, and placed it on the woman's stomach, as she lay in this horizontal position; when another person, at her request, placed a smaller stone on the large one, and with a heavy iron sledge-hammer broke it into twenty pieces. All this occupied about a quarter of an hour, during the whole of which time the woman evinced no appearance of shrinking; and in conversing with her after she rose there was not the slightest evidence of any inconvenience being felt by her from the exertion.

That much depends upon physical organization, as regards the force of muscular contraction, is evinced by the fact of the great difference in the various races of mankind. On our own continent, numerous opportunities have occurred for witnessing the inferiority, in strength, of the aborigines to the white settlers. Péron[1] took with him, in his voyage round the world, one of Regnier's dynamometers, which indicate the relative force of men and animals. He directed his attention to the strength of the arms and loins, making trial on several individuals of different nations; twelve natives of Van Diemen's Land; seventeen of New Holland; fifty-six of the island of Timor; seventeen Frenchmen belonging to the expedition, and fourteen Englishmen in the colony of New South Wales. The following was the mean result:—

	STRENGTH.	
	Of the Arms. *Kilogrammes.*[2]	Of the Loins. *Myriagrammes.*
1. Van Diemen's Land,	50·6	
2. New Holland,	50·8	10·2
3. Timor,	58·7	11·6
4. French,	69·2	15·2
5. English,	71·4	16·3

The highest numbers, in the first and second divisions, were respectively 60 and 62; the lowest in the fifth, 63; in the highest 83, for the strength of the arms. In the power of the loins, the highest amongst the New Hollanders was 13; the lowest of the English, 12·7.[3]

The force of muscular contraction is also largely increased by the proper exercise of the muscles. Hence the utility of the ancient gymnasia. In early times, muscular energy commanded respect and admiration. It was the safeguard of individuals and families, and the protection of nations; and it was esteemed a matter of national policy to encourage its acquisition. In modern times, the invention of gunpowder having altered the system of warfare, and given to skill the

[1] Voyage, &c., tom. i. chap. xx. p. 446; and t. ii. p. 461; and Lawrence's Lectures on Physiology, &c., p. 404, Lond., 1819.

[2] The approximate value of a *kilogramme* is about two pounds avoirdupois:—of a *myriagramme* about twenty.

[3] See Quetelet, Sur l'Homme, &c., Paris, 1835, or English edit., by Dr. R. Knox, p. 67, Edinburgh, 1842. Prof. Forbes, of Edinburgh, in London and Edinburgh Phil. Magazine, for March, 1837, p. 197; and in Dunglison's American Med. Intelligencer, for May 15, 1837, p. 74; in which are detailed experiments on the weight, height, and strength of above eight hundred individuals, natives of England, Scotland, Ireland, and Belgium.

superiority which strength communicated in personal combats, institutions for the developement of the muscular system have been abandoned, until of comparatively late years. They afford us striking examples of the value of muscular exertion, not only in giving energy and pliancy to the frame, but as a means of preserving health.

The mean effect of the labour of an active man, working to the greatest possible advantage, and without impediment, is usually estimated to be sufficient to raise ten pounds, ten feet in a second for ten hours in a day; or to raise one hundred pounds, which is the weight of twelve wine gallons of water, one foot in a second, or thirty-six thousand feet in a day; or three millions, six hundred thousand pounds, or four hundred and thirty-two thousand gallons, one foot in a day. Dr. Desaguliers affirms, that the weakest men who are in health, and not too fat, lift about one hundred and twenty-five pounds; and the strongest of ordinary men four hundred pounds. Topham lifted eight hundred. The daily work of a horse is estimated to be equal to that of five or six men.

In insects, the force of muscular contraction appears to be greater in proportion to their size than in any other animals. The *Lucanus cervus* or *Stag Beetle* has been known to gnaw a hole of an inch diameter in the side of an iron canister in which it had been confined, and many striking examples of a similar kind are given hereafter under the head of LEAPING.

In the *duration* of muscular contraction we notice considerable difference between the voluntary and involuntary muscles; the latter being much more rapid and alternating. The same remark applies to the voluntary muscles, when excited by another stimulus than that of the will. Contraction, excited by volition, can be maintained for a considerable time: of this we have examples in bearing a burden; the act of standing; holding the arm extended from the body, &c. In all these cases, the contractility of the muscles is sooner or later exhausted; fatigue is experienced; and it becomes necessary to give them rest; the power of contractility, however, is soon resumed, and they can be again put in action. This law of intermission in muscular action appears absolute;—relaxation being followed by contraction, in every organ, from the commencement of life until its final cessation. The intermission, has, indeed, by many physiologists, been held to prevail—to a slight extent only, it is true—during what we are in the habit of considering continuous muscular contraction. In proof of this, they cite the fact, that when we put the tip of the finger into the meatus auditorius externus, we hear a kind of buzzing or humming, which does not occur when an inert body is introduced.[1] There are, however, other actions going on in the finger besides muscular contraction; and the buzzing might, with as much propriety, be referred to the noise made by the progression of fluids in the vessels, as to the oscillations of muscular contraction and relaxation. We know not, in truth, whence the sound immediately proceeds.

Dr. Brown-Séquard[2] found, that when he kept his forearm extended

[1] Wollaston, in Philosoph. Transact. for 1810, p. 2.
[2] Medical Examiner, July, 1852, p. 428.

with a weight in one of his hands, and felt his power to continue it so was lost, if an assistant applied the wires of an electro-magnetic machine to his shoulder and forearm so as to excite the biceps and some other muscles, he could maintain the forearm nearly in the same position for several minutes longer; whence he concludes, that it is the action of a part of the brain, and not of the muscles which is deficient when the will is unable to maintain a permanent contraction of them.

In the *velocity* of muscular contraction, much difference exists, according to the stimulus which sets it in action. If we apply galvanism to a muscle, we find the contractions at first exceedingly rapid; but they become progressively feebler, and require a stronger stimulus, until their irritability appears to be exhausted. Irritating the nerve in these cases is found to produce a greater effect, than when the stimulus is applied directly to the muscle. The velocity of voluntary contraction is, of course, variable, being regulated entirely by the will. We have, in various classes of the animal kingdom, remarkable instances of this velocity. The motions of the racer, greyhound, practised runner, the fingers in playing on musical instruments—as the violin, flute, piano-forte—and in writing; of the voice in enunciation, and of the upper and lower limbs in striking, leaping, and kicking, convey a general notion of this rapidity of contraction; and how nicely, in many cases, it must be regulated by volition. The fleetest race-horse on record was capable of going, for a short distance, at the rate of a mile per minute; yet this is trifling, when compared with the velocity of certain birds, which can, with facility, wheel round and round the most rapid racer in circles of immense diameters,—and with that of numerous small insects, which accompany us, with apparent facility, when we travel with great rapidity, even against the wind.

It has frequently excited surprise, how porpoises—animated propellers—can sail around vessels in rapid motion, and how migratory birds can support themselves so long upon the wing as to reach the country of their migration; and, at the same time, live without food during their aerial voyage. The difficulties of the subject have impelled many to deny the fact of their migration, and excited others to form extravagant theories to account for the preservation of the birds during the winter months; but if we attend to their excessive velocity, the difficulties, in a great measure, vanish. "Nothing," says Wilson,[1] "is more common in Pennsylvania than to see large flocks of the bluebirds, in spring and fall, passing at considerable heights in the air,—from the south in the former, from the north in the latter season. The Bermudas are said to be six hundred miles from the nearest part of the continent. This may seem an extraordinary flight for so small a bird; but it is a fact that it is performed. If we suppose the bluebird to fly only at the rate of a mile a minute, which is less than I have actually ascertained them to do over land, ten or twelve hours would be sufficient to accomplish the journey." Montagu, a celebrated ornithologist, estimates the rapidity with which hawks and many other birds occasionally fly to be not less than one hundred and fifty miles an hour; and that one hundred miles per hour

[1] American Ornithology, ii. 178.

is certainly not beyond a fair computation for the continuance of their migration. Major Cartwright, on the coast of Labrador, found by repeated observations, that the flight of the eider duck is at the rate of ninety miles an hour; yet it has not been esteemed very remarkable for its swiftness. Sir George Cayley computes the rate of flight of the common crow at nearly twenty-five miles an hour. Spallanzani found that of the swallow about ninety-two miles an hour; and he conjectures, that the velocity of the swift is nearly three times greater. A falcon belonging to Henry IV. of France escaped from Fontainbleau, and was in twenty-four hours afterwards at Malta,—a distance computed to be not less than one thousand three hundred and fifty miles, making a velocity of nearly fifty-seven miles an hour, supposing the falcon to have been on the wing the whole time; but, as such birds never fly by night, if we allow the day to have been at the longest, his flight was perhaps at the rate of seventy-five miles per hour. It is not probable, however, as Montagu observes, that it had either so many hours of light in the twenty-four to perform its journey, or that it was retaken at the moment of its arrival.[1] A society of pigeon-fanciers from Antwerp despatched ninety pigeons from Paris, the first of which returned in four hours and a half, at a rate of nearly fifty miles an hour. Out of one hundred and ten pigeons, carried from Brussels to London in the summer of 1830, and let fly from London on July 19th, at a quarter before nine A. M., one reached Antwerp, one hundred and eighty-six miles distant, at eighteen minutes past two, or in five and a half hours,—being at the rate of nearly thirty-four miles an hour. In another case, one went from London to Maestricht, two hundred and sixty miles, in six and a quarter hours. In January, 1831, two pigeons, carried from Liskeard to London, were let loose in London. One reached Liskeard, two hundred and twenty miles distant, in six hours; the other in a quarter of an hour more.[2] There is an instance of the migratory or passenger pigeon,—*Columba migratoria* of Wilson—having been shot in Fifeshire, in Scotland. It was the first ever seen in Great Britain, and had been forced over, it was imagined, by unusually strong westerly gales.[3]

The velocity of the contraction of the muscles of the wings, in these rapid flights, is incalculable. The possible velocity, in any case, must be greatly dependent upon habit. Nothing can be more awkward than the first attempts at writing, drawing, playing on musical instruments, or performing any mechanical process in the arts; and what a contrast is afforded by the astonishing celerity, which practice never fails to confer in any one of those varieties of muscular contraction! In running, leaping, wrestling, dancing, or any other motion of the body, one person can execute with facility what another, with equally favourable original powers, cannot effect, because he has not previously and frequently made the attempt. Prize-fighting affords an instance of this kind of muscular velocity and precision acquired by habit,—the practised boxer being able to inflict his blow and return his arm to the guard so quickly as almost to elude the sight. By considering

[1] Fleming's Philosophy of Zoology, ii. 42, Edinb., 1822.
[2] Turner's History of the World, Amer. edit., i. 259, New York, 1832.
[3] New Monthly Magazine for 1826.

the muscular motions, employed in transporting the body of the fleetest horse, Haller concluded, that the elevation of the leg must have been performed in $\frac{1}{70}$th of a second. He calculates, that the *rectus femoris*,—the large muscle which is attached to the knee-pan and extends the leg,—is shortened three inches in the $\frac{1}{25}$th of a second in the most rapid movements of man. But, he adds, the quickest motions are executed by the muscles concerned in the articulation of the voice. He himself, in one experiment, pronounced fifteen hundred letters in a minute; and as the relaxation of a muscle occupies as much time as its contraction, the contraction of a muscle, in pronouncing one of these letters, must have been executed in $\frac{1}{3000}$th part of a minute; and in much less time in some letters, which require repeated contractions of the same muscle or muscles as *r*. If the tremors, that occur in the pronunciation of this letter, be estimated at ten, the muscles concerned in it must have contracted in Haller's experiment, in $\frac{1}{30000}$th part of a minute.[1] It has been calculated, that all the tones of which the human voice is capable are produced by a variation of not more than one-fifth of an inch in the length of the vocal cords; and that in man the variation required to pass from one interval to another will not be more than $\frac{1}{1200}$th of an inch. These cases are, however, far exceeded by the rapidity of the vibrations of the wings of insects, which can be estimated from the musical tone they induce, experiment having shown the number of vibrations required to produce any given note. The vibrations of their wings have thus been found to amount to several thousands per second.

It has been the opinion of many physiologists and metaphysicians, that muscular contraction is only directed by volition within certain limits of velocity; and that when it exceeds a certain velocity it depends upon habit. The effects of volition have, in this respect, been divided into the *immediate* and *remote*. Of the first we have examples in the formation of certain vocal and articulate sounds; and in certain motions of the joints, as in the production of voice, speech, and locomotion. In the second, those actions are included which we conceive to be within our power, but in which we think of the end to be obtained, without attending to the mechanical means. "In learning a language, for example," says Dr. Bostock,[2] "we begin by imitating the pronunciation of the words, and use a direct effort to put the organs of speech in the proper form. By degrees, however, we become familiar with this part of the operation, and think only of the words that are to be employed, or even the meaning that is to be conveyed by them. In learning music, we begin by imitating particular motions of the fingers, but at length the fingers are disregarded, and we only consider what sounds will follow from certain notes, without thinking of the mechanical way in which the notes are produced." In these, however, and in all other cases that can be brought forward, it is difficult to conceive how the effect can be produced without the agency of volition,—obscure it is true, but still in action. The case of reading is often assumed, as confirming the view that invokes habit; yet, if a letter be inverted, we immediately detect it; and although, by habit,

[1] Elementa Physiologiæ, &c., lib. xi. 2, Lausan., 1757–1766.
[2] Physiology, edit. cit., p. 774, Lond., 1836.

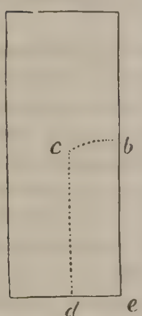
we may have acquired extreme facility in playing the notes of a rapid musical movement, no doubt, we think, ought to exist, that an effort of volition is exerted on each note composing it,—inasmuch as there is no natural sequence of sounds; and hence there appears no cogent reason, why one should follow rather than another, unless a controlling effort of the will were exerted.

With regard to the *extent* of muscular contraction, this must of course be partly regulated by volition; but it is also greatly owing to the length of the muscular fibres. The greater the length, of course the greater the decurtation during contraction. We shall see, likewise, that this depends upon the kind of lever, which the bone forms, and the distance at which the muscle is inserted from the joint or fulcrum.

Before passing to the examination of special movements, it will be necessary to consider briefly certain elementary principles of mechanics, most of which are materially concerned in every explanation, and without some knowledge of which such explanation would, of course, be obscure or unintelligible. Were we, as M. Magendie[1] has remarked, to investigate narrowly every motion of the body, we should find the applicability of almost all the laws of mechanics to them.

If we take a rod of wood or metal, of uniform matter throughout, and support it at the middle, either like the beam of a balance, or on a pointed body, we find, that the two ends accurately balance each other; and if we add weights at corresponding parts of each arm of the beam, that is, at parts equidistant from the point of suspension, the balance will still be maintained. The point by which the beam is suspended, or at which it is equilibrious, is called its *centre of gravity;* and, in every mass of matter, there is a point of this kind, about which all the parts balance or are equilibrious; or, in other words, they have all a centre of gravity or inertia. The centre of gravity, in a mass of regular form and uniform substance, as in the parallelograms, Figs. 355 and 356, is easily determined, inasmuch as it must necessarily occupy the centre *c;* but in bodies that are irregular, either as regards density or form, it has to be determined by rules of calculation, to be found in all works on physics; but which it is unnecessary to adduce here.

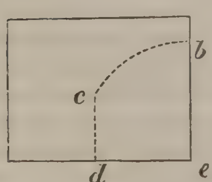
Fig. 355.



Centre of Gravity.

The nearer the centre of gravity is to the soil on which the body rests, the more stable is the equilibrium. In order that the Figures 355 and 356 shall be overturned from left to right, the whole mass must turn upon *e* as upon a pivot; the centre of gravity describing the curve *c b*, and the whole mass being lifted in the same degree. In Fig. 355, the curve is nearly horizontal, owing to the narrowness of the base and the height of the centre of gravity. In Fig. 356, on the other hand, whose base is broad and the centre of gravity

Fig. 356.



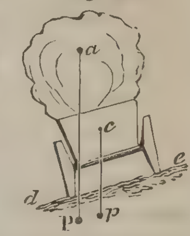
Centre of Gravity.

[1] Précis, &c., edit. cit., i. 276.

low, the curve rises considerably; the resistance to overturning is consequently nearly equal to the whole weight of the body, and the equilibrium necessarily firm.

The *condition of equilibrium* of a body resting upon a plane is such, that a perpendicular, let fall from the centre of gravity, shall fall within the points by which it touches the plane. This perpendicular is called *vertical line* or *line of direction*, being that in which it tends naturally to descend to the earth; and the space comprised between the points by which the body touches the soil is called *base of sustentation*. We can now understand, why a wagon, loaded with heavy goods, may pass with safety along a sloping road; whilst, if it be loaded to a greater height with a lighter substance, it may be readily overturned. When the wagon is loaded with metal, the centre of gravity is low, as at *c*, Fig. 357; the vertical line *c p* falls considerably within the base of sustentation; and the centre describes a rising path; but in the other case the centre is thrown higher, to *a*; and the vertical line falls very near the wheel, or on the outside of it, and consequently of the base, whilst the centre describes a falling path.

Fig. 357.



Condition of Equilibrium.

Of two hollow columns, formed of an equal quantity of the same matter, and of the same height, that which has the largest cavity will be the stronger; and of two columns of the same diameter, but of different heights, the higher will be the weaker.

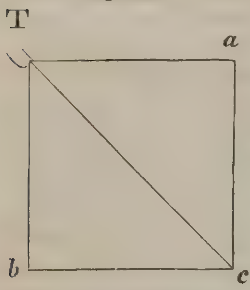
All bodies tend to continue in the state of motion or of rest, so as to render force necessary to change their state. This property is called the *inertia of motion*, or of *rest*, as the case may be. When a carriage is about to be moved by horses, considerable effort is necessary to overcome the *inertia of rest;* but if it moves with velocity, effort is required to arrest it, or to overcome the *inertia of motion*. We can thus understand why, if a horse start unexpectedly, it is apt to get rid of its burden; and why an unpractised rider is projected over his horse's head if it stops suddenly. In the former case, the inertia of rest is the cause of his being thrown; in the latter, the inertia of motion. The danger of attempting to leap from a carriage, when the horses have taken fright, is thus rendered apparent. The traveller has acquired the same velocity as the vehicle; and if he leaps from it, he is thrown to the ground with that velocity; thus incurring an almost certain injury to avoid one remotely contingent.

The *force*, *momentum*, or *quantity of motion* in a body is measured by the velocity, multiplied into the quantity of matter. A cannon-ball, for example, may be rolled so gently against a man's leg, as not even to bruise it; but if it be projected by means of gunpowder, it may mow down a dense column of men, or penetrate the most solid substance. If a man be running, and strike against another who is standing, a certain shock is received by both; but if both be running in opposite directions with the same velocity, the shock will be doubled.

The subject of the direction of forces applies to most cases of muscular movement. Where only one force acts upon a body, the body proceeds in the direction in which the force is exerted, as in the case

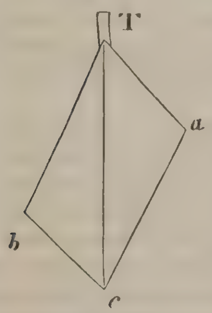
of a bullet fired from a gun; but if two or more forces act upon it at the same time, the direction of its motion will be a middle course between the direction of the separate forces. This course is called the *resulting direction*, that is, *resulting* from the *composition of the forces.* Let us suppose two forces *a* T and *b* T in Fig. 358, acting upon the body T, which may be regarded as the tendon of a muscle, and the two forces as the power developed by muscular fibres holding the same situation; the result will be the same, whether they act together or in succession. For example, if the force *a* T is sufficient to draw T to *a*, and immediately afterwards the force *b* T be exerted upon it, the tendon will be at *c*, the place towards which it would be drawn by the simultaneous action of the two forces or fibres. If, therefore, we complete the figure by drawing *a c* equal and parallel to T *b*, and *c b* equal and parallel to *a* T, we have the *parallelogram of forces*, as it is called, of which the diagonal shows the *resultant* of the forces, and the course of the body on which they act. In the case, assumed in Fig. 358, the forces are equal. If not, the parallelogram may result as in Fig. 360; in which T *c* will, again, be the resultant of the forces *a* T and T *b*, or we may have the arrangement in Fig. 359.

Fig. 358.



Composition of Forces.

Fig. 359.

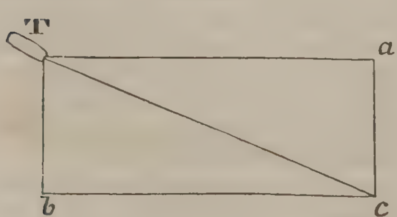


Composition of Forces.

By these parallelograms, we are enabled, also, to resolve the resultant into its component forces. Suppose, for example, we desire to know the quantity of force in the resultant, T *c*, Fig. 358, which is capable of acting in the directions T *a* and T *b;* it is only necessary to draw, from the point *c*, *c a* parallel to T *b*, and *c b* parallel to T *a;* and the lines T *a* and T *b*, cut off by these, will be the forces into which it may be resolved. The same applies to Figs. 359 and 360, and to every other of the kind.

Friction is the resistance necessary to be overcome in making one body slide over another; and *adhesion* the force, which unites two polished bodies when applied to each other,—a force, which is measured by the perpendicular effort necessary for separating the two bodies. The more polished the surfaces in contact, the greater is the adhesion, and the less the friction; so that where the object is merely to facilitate the sliding of one surface over another, it will be always advantageous to make the surfaces polished, or to put a liquid between them.

Fig. 360.

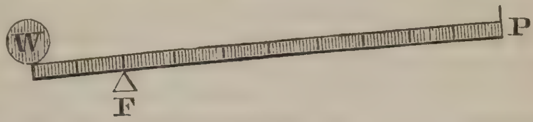


Composition of Forces.

A beam or rod of any kind, resting at one part on a prop or support, which thus becomes its

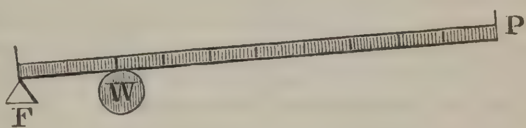
centre of motion, is a *lever*. The ten inch beam, P W, Fig. 361, is a lever, of which F may be considered the *prop* or *fulcrum ;* P, the part at which the *power* is applied, and W, the point of application of the *weight* or *resistance.* In every lever we distinguish three points:—the *fulcrum, power*, and *resistance;* and, according to the relative position of these points, the lever is said to be of the *first, second*, or *third kind.* In a lever of the first kind, the fulcrum is between the resistance and power, as in Fig. 361; F being the fulcrum on which the beam rests and turns; P, the power; and W, the weight or resistance. We have numerous familiar examples of this lever; the crowbar in elevating a weight; the handle of a pump; a pair of scales; a steelyard, &c. A *lever of the second kind* has the resistance W, Fig. 362, between the power P and the fulcrum F; the fulcrum and power occupying each one extremity. The rudder of a ship, a wheelbarrow, and nut-crackers, are varieties of this kind of lever. In a *lever of the third kind*, the powet P is between the resistance W, and the fulcrum F, Fig. 363; the resistance and the fulcrum occupying each one extremity of the lever. In the last two levers, the weight and the power change places. Tongs and shears are levers of this kind; also, a long ladder raised against a wall by the efforts of a man: here the fulcrum is at the part of the ladder which rests on the ground; the power is exerted by the man; and the resistance is the ladder above him.

Fig. 361.



Lever of the first kind.

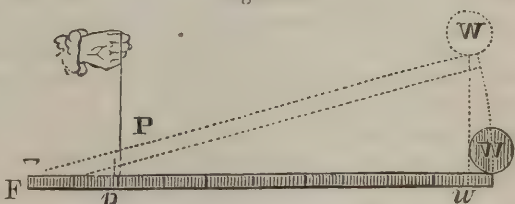
Fig. 362.



Lever of the second kind.

In all levers are distinguished,—the *arm of the power* and the *arm of the resistance.* The former is the distance comprised between the power and the fulcrum, P F, Figs. 361, 362, and 363; and the latter is the distance W F, or that between the weight and the fulcrum. When, in the lever of the first kind, the fulcrum occupies the middle, the lever is said to have equal arms; but if it be nearer the power or the resistance, it is said to be a lever with unequal arms.

Fig. 363.



Lever of the third kind.

The length of the arm of the lever gives more or less advantage to the power, or the resistance, as the case may be. In a lever of the first kind, with equal arms, complete equilibrium would exist, provided the beam were alike in every other respect. But if the arm of the power be longer than that of the resistance, the resistance is to the power as the length of the arm of the power is to that of the arm of the resistance; so that if the former be double or triple the latter, the power need only be one-half or one-third of the resistance, in order that the two forces may be in equilibrium. A reference to the figures will exhibit this in a clear light. The three levers are all presumed to be of equal substance throughout, and to be ten inches, or ten feet in length. The arm of the power, in Fig. 361, is the distance P F, equal to eight of those divisions; whilst that of the resistance is W F, equal to two of them. The advantage of the former over the latter is, consequently, in the proportion of eight to two, or as four to one; in other words, the power need only be one-fourth of the resistance, in order that the two forces may be equilibrious. In the lever of the second kind, the proportion of the arm P F of the power is to that of the resistance, W F, as ten—the whole length of the lever—to two; or five to one; whilst, in the lever of the third kind, it is as two to ten, or as one to five; in other words, to be equilibrious, the power must be five times greater than the resistance. We see, therefore, that in the lever of the second kind, the arm of the power must necessarily be longer than that of the resistance, since the power and the fulcrum are separated from each other by the whole length of the lever; hence this kind of lever must always be advantageous to the power; whilst the lever of the third kind, for like reasons, must always be unfavourable to it, seeing that the arm of the resistance is the whole length of the lever, and, therefore, necessarily greater than that of the power.

It can now be understood why a lever of the first kind should be most favourable to equilibrium; one of the second for overcoming resistance; and one of the third for rapidity and extent of motion: for whilst, in Fig. 363, the power is moving through the minute arc at P, in order that the lever may assume the position indicated by the dotted lines F W, the weight or resistance is moving through the much more considerable space W w.

The direction in which the power is inserted into the lever likewise demands notice. When perpendicular to the lever, it acts with the greatest advantage,—the whole of the force developed being employed in surmounting the resistance; whilst if inserted obliquely a part of the force is employed in tending to move the lever in its own direction; and this part is destroyed by the resistance of the fulcrum.

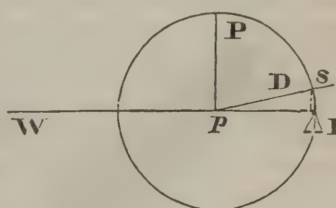
Lastly: the general principles of equilibrium in levers consist in this;—that whatever may be the direction in which the power and resistance are acting, they must always be to one another inversely as the perpendiculars drawn from the fulcrum to their lines of direction. In Fig. 363, for example, the line of direction of the upper weight is W w; that of the power P p; and, to keep the lever in equilibrium in this position, the forces must be to one another inversely as F w to F p.

In applying these mechanical principles to the illustration of muscular motion, we must, in the first place, regard each movable bone as a

lever, whose fulcrum or centre of motion is in its joint; the power at the insertion of the muscle; and the resistance in its own weight and that of the parts which it supports. In different parts of the skeleton we find the three kinds of levers. Each of the vertebræ of the back forms, with the one immediately beneath it, a lever of the first kind,—the fulcrum being seated in the middle of the under surface of the body of the vertebra. The foot, when we stand upon the toe, is a lever of the second kind,—the fulcrum being in the part of the toes resting upon the soil; the power in the muscles inserted into the heel, and the resistance in the ankle joint, on which the whole weight of the body rests. Of levers of the third kind we have numerous instances; of which the deltoid, to be described presently, is one. In this, as in other cases, the applicability of the principle, laid down regarding the arms of the lever, &c., is seen, and we find, that, in the generality of cases, the power is inserted into the lever so near to the fulcrum, that considerable force must be exerted to raise an inconsiderable weight;—that so far, consequently, mechanical disadvantage results; but such disadvantage enters into the economy of nature, and is attended with so many valuable concomitants as to compensate richly for the expense of power. Some of these causes, that tend to diminish the effect of the forces, we shall first consider, and afterwards attempt to show the advantages resulting from these and similar arrangements in effecting the wonderful, complicate operations of the muscular system.

In elucidation of this subject, we may take, with Haller,[1] the case of the deltoid—the large muscle, which constitutes the fleshy mass on the top of the arm, and whose office it is to raise the upper extremity. Let W F, Fig. 364, represent the os humeri, with a weight W at the elbow, to be raised by the deltoid D. The fulcrum F is necessarily, in this case, in the shoulder-joint; and the muscle D is inserted much nearer to the fulcrum than to the end of the bone on which the weight rests; the arm of the power *P* F—(supposing, for a moment, that it is acting at this part with every advantage, which we shall see presently it is not)—is, consequently much shorter than that of the resistance W F, which, as in all levers of the third kind, occupies the whole length of the lever. In estimating the effect from this cause alone upon the power to be exerted by the deltoid, we may suppose, that the arm of the power is to that of the resistance as 1 to 3;—the deltoid being inserted into the humerus about one-third down. Now, if we raise a weight of fifty-five pounds in this way, and add five pounds for the weight of the limb—which may be conceived to act entirely at the end of the bone—the power, which the deltoid must exert to produce the effect, is equal not to sixty pounds, but to three times sixty or one hundred and eighty pounds.

Fig. 364.

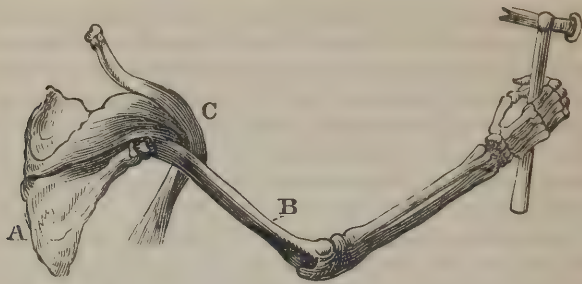


Action of the Deltoid.

[1] Elementa Physiologiæ, lib. xi. 2.

Figures 364 and 365 exhibit the disadvantages of the deltoid, so far as regards the place of its insertion into the lever; but many muscles

Fig. 365.



Action of the Deltoid.

A. The scapula. B. The os humeri. C. The deltoid.

have insertions much less favourable than it. The biceps, D, for example, in Fig. 366,—the muscle which bends the forearm on the arm,—is attached to the forearm ten times nearer the elbow-joint or fulcrum than to the extremity of the lever; and if we apply the calculation to it,—supposing the weight of the globe, in the palm of the hand, to be fifty-five pounds and the weight of the limb five pounds,—it would have to act with a force equal to sixty times ten, or six hundred pounds, to raise the weight.

Muscles, again, are attached to the bones at unfavourable angles. If they were inserted at right angles in the direction P *p*, Fig. 364, the whole power would be effectually applied in moving the limb. On the other hand, if the muscle were parallel to the bone, the resistance would be infinite, and no effect could result. In the animal it rarely happens, that the muscle is inserted at the most favourable angle; it is

Fig. 366.

Action of the Biceps.

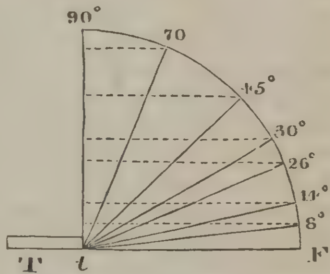
A. The os humeri. B. The ulna. C. The radius. D. The biceps. E. Insertion of the biceps into the radius.

generally much smaller than a right angle. Reverting to the deltoid, this muscle is inserted into the humerus at an angle of about ten degrees. Now, a power acting obliquely upon a lever, is to one acting

perpendicularly, as the sine of inclination, represented by the dotted line F s, Fig. 364, to the whole sine P *p*. In the case of the deltoid, the proportion is as 1,736,482 to 10,000,000. Wherefore, if the muscle had to contract with a force of one hundred and eighty pounds, owing to the disadvantage of its insertion near the fulcrum, it would have, from the two causes combined, to exert a force equal to 1,058 pounds.

Again, the direction in which the fibres are inserted into the tendon has great influence on the power developed by the muscle. There are few straight muscles, in which all the fibres have the same direction as the tendon. Fig. 367 exhibits the loss of power, which the fibres must sustain in proportion to the angle of insertion. The fibre *t* F would, of course, exert its whole force upon the tendon, whilst the fibre *t* 90°, by its contraction, would merely displace the tendon. Now, the force exerted is, in such case, to the effective force, —that is, to that which acts in moving the limb,—as the whole sine *t* F is to the sines of the angles at which the fibres join the tendon represented by the dotted lines. Borelli and Sturm have calculated these proportions as follows:—At an angle of 30°, they are as 100 to 87; at 45° as 100 to 70; at 26° as 100 to 89; at 14° as 100 to 97; and at 8° as 100 to 99.

Fig. 367.



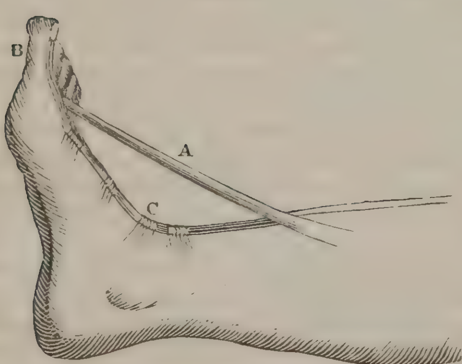
Insertion of Fibres into Tendon.

The largest angle, formed by the outer fibres of the deltoid, is estimated by Haller at 30°: the smallest about 8°. If this disadvantage be taken into account, the deltoid will have to contract with a force equal to 1,284 pounds, to raise fifty-five pounds at the elbow. It is farther contended by Borelli, Sturm, and Haller, that the force of the muscle, as estimated in the preceding calculations, must be doubled, seeing that it has to exert as much force in resisting the bone which affords a fixed point at one extremity, as in elevating the weight at the other. This estimate, if admitted, would elevate the force, to be exerted by the deltoid in raising the fifty pounds, to 2,568 pounds. Lastly: Much force is spent when a muscle passes over many joints; antagonist muscles must, likewise, exert an influence of the kind, consuming a certain portion of the force developed in the contraction of the muscle.

On the other hand, there are arrangements that augment the power developed by muscles;—as the thick articular extremities of bones; the patella and sesamoid bones in general; all of which enlarge the angle, at which the tendon is inserted into the bone or lever. The projecting processes for muscular attachments, as the trochanters, protuberance of the os calcis, spinous processes of the vertebræ, &c., augment the arm of the lever, and are thus inservient to a like valuable purpose. The smoothness of the articular surfaces of bones, tipped, as they are, with cartilage, and the synovia, which lubricates the joints by diminishing friction, as well as the bursæ mucosæ, which are

interposed wherever there is much pressure or friction, also aids the power. Trochleæ or pulleys act only in directing the force, without augmenting its amount; and the same may be said of the bony canals and tendinous sheaths, by which the tendons of the muscles, especially those passing to the fingers and toes, are kept in their proper course. Still, it must be admitted, that, as regards the effort to be exerted by muscles, it must, in almost all cases, be much greater than the resistance to be overcome. The very fact of the lever of the third kind being that which prevails in our movements shows this. The mere mechanician has conceived this to be an unwise construction, and that there is a needless expense of force for the attainment of a determinate end. In all cases we find, that the expense of power has been but little regarded in the construction of the frame; nor is it necessary that it should have been. It must be recollected, that the contraction of the muscle is under the nervous influence, and that, within certain limits, the force, to be employed, is regulated by the influx sent by it to the muscle. The great object in the formation of the body appears to have been—to unite symmetry and convenience with the attainment of great velocity and extent of motion, so that whilst the power is moving through a small space, the weight or resistance shall move rapidly through one more extensive. We have seen that, in these respects, the lever of the third kind is most fitting. With the others less power might be required; but there would be less extent of motion and velocity, whilst the symmetry and convenience of the body would be destroyed. Suppose, for example, that in Fig. 366, the biceps—instead of being inserted at E, near the elbow—had passed on to the wrist,—or, to simplify the matter, to the extremity of the member; it would assuredly have acted with more force—the lever having been changed into one of the second kind,—but the hand would have lost that velocity and extent of motion, which are so important to it; and the course of the muscle would have been so modified as to convert the convenient and symmetrical member into a cumbrous, webbed instrument, badly adapted for the multitudinous purposes to which it has to be applied.

Fig. 368.



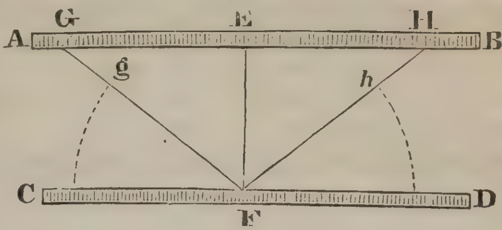
Tendon of the Great Toe.

The same effect results, as Sir Charles Bell[1] has remarked, from the course of tendons and their confinement by sheaths, strengthened by ligaments. If the tendon A, Fig. 368, took the shortest course to its termination at B, it would draw up the toe with more force; but the toe would lose its velocity of movement.

[1] Animal Mechanics, Library of Useful Knowledge, p. 27, Lond., 1829.

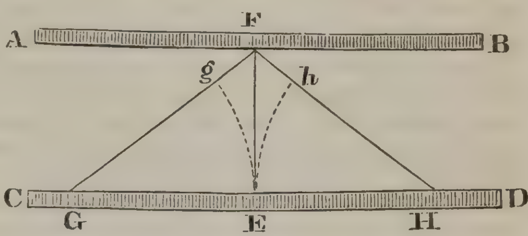
To favour this velocity, we find that the majority of muscles are inserted obliquely into their levers, and the fibres into the tendons. By this arrangement, as we have proved, considerable loss of power results; but in the majority of cases, the motion is effected by a less degree of decurtation than if the muscles were straight. Let A B and C D, Figs. 369 and 370, be parts of two ribs that are parallel, and continue parallel till brought into contact by the action of the straight muscle E F; or by that of the oblique muscles F G and F H. Now it is obvious, that when the point E comes in contact with F, the length of the straight muscle E F must be null; whilst that of the oblique muscles will only have experienced a decurtation equal to G g and H h, Fig. 369; and to F g and F h, Fig. 370. It is clear, also, that, in these cases, the straight muscles can never so contract as to admit of a close approximation of the ribs; whilst the oblique muscles will admit of this to a much greater extent. We can, therefore, understand, why the intercostal muscles pass obliquely from one rib to another, as at D and B C, Fig. 371, instead of in a direction perpendicular to the two ribs as at A.

Fig. 369.



Action of Intercostal Muscles.

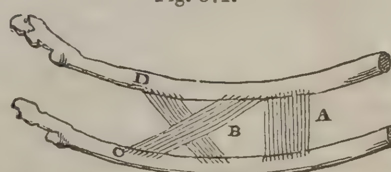
Fig. 370.



Action of Intercostal Muscles.

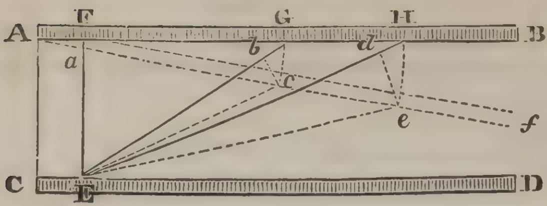
There are cases, however, in which a straight muscle may pass between two parallel ribs, and carry them through a given space, with less decurtation of fibres, than any oblique muscle, which has the same origin; but is inserted at a greater distance from the centre of motion, and acts through the medium of a longer lever. Moreover, a muscle, with a less degree of obliquity, may be so situate as to carry the bones through a given space, with a less decurtation of fibres than any other muscle having the same origin but a much greater degree of obliquity. Suppose A B and C D, Fig. 372, to be two parallel ribs, of which A B is movable about A as a centre; and sup-

Fig. 371.



Action of Intercostals.

Fig. 372.

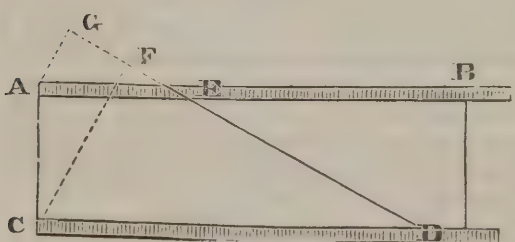


Action of Intercostals.

pose it to be brought by the action of the straight muscle E F, and of the oblique muscles E G and E H, into the position A *f*. The points of insertion of the muscles will now be at *a*, *c* and *e*, after having traversed the spaces F *a*, G *c*, and H *e*. If we now, from the point E, as a centre, describe the arcs *c b* and *e d*; the spaces *d* H and *b* G will indicate the degree of decurtation, which the oblique muscles have experienced, and *a* F that of the straight muscle. This figure also shows, that when the muscles change the relative position of any two bones, they at the same time change the direction of their own action, and vary their lever. When the rib A B is brought into the position A *f*, the muscles E G and E H, by being brought down to *c* and *e*, have assumed the positions E *c* and E *e*; and have, consequently, changed their length, situation, obliquity, and leverage.

Again, of the muscles, which are attached to ribs that are parallel, equally movable, and situate at right angles to the spine, those which pass perpendicularly from one rib to the other will act upon each with equal leverage; and each will approach the other with the same velocity; whilst those that pass obliquely from one to the other, will make them approach with different velocities;—a principle which is strikingly applicable to the intercostal muscles. Let us suppose A B and C D, Fig. 373, to be two parallel ribs, articulated with the spine at A and C, and equally movable on these centres of motion. Let D B represent a straight muscle, passing directly from the one rib to the other; and D E an oblique muscle. The levers of D B, according to the mechanical principles laid down, will be A B and C D, perpendiculars drawn from the centres of motion to the line of direction of the power.

Fig. 373.

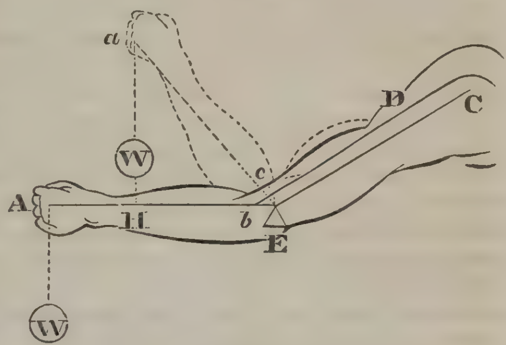


Action of Intercostals.

These levers being parallel are of course equal; but the levers of D E will be C F and A G,—also perpendiculars drawn from the centres of motion to the line of direction of the power. These levers are of different lengths; and, accordingly, the muscle must act with different degrees of force on the two ribs: so that it will cause C D, on which it acts with the longest lever, to approach A B faster than it makes the latter approach the former,—in the ratio of C F to A G, or with three times the velocity.

In all muscular motions, the levers of the power and resistance are undergoing variations; so that the degree of power, necessary to be developed in one position of the member, may be much less than in another. The case of the biceps already referred to, elucidates this. Let E C, Fig. 374, represent the os humeri; E A the forearm; E the elbow-joint; W, a weight or resistance hung at the wrist, and D the biceps muscle, inserted at b, a tenth of the distance down the forearm. It is manifest, that the force, necessary for bending the arm, must be much greater when it is in the position A E than in that of E a. The lever of the resistance, in the former case, is the whole length of the forearm; or, in other words, the perpendicular drawn from the fulcrum to the line of direction of the weight W; but, when the arm is raised to a, the lever of the resistance is no longer E A, but E H; but not only is the lever of the resistance shortened; that of the power is augmented. The lever of the biceps, when the forearm is horizontal, is the dotted perpendicular drawn from the fulcrum at the elbow to the line of direction of the muscle; but when the forearm is bent to the position E a, the disposition of the muscle is also modified. It assumes the position occupied by the dotted line, which is farther distant from the fulcrum; and the lever of the power is consequently increased. In this case, then, of the action of the biceps, in proportion as we raise the arm, the mechanical disadvantages become less and less; the lever of the power increasing, whilst that of the resistance diminishes.

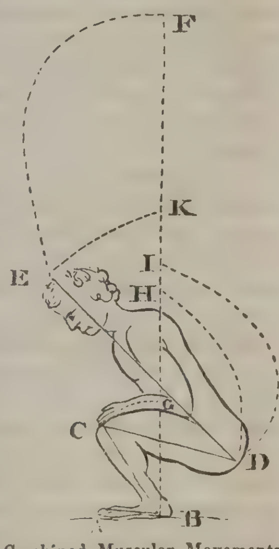
Fig. 374.



Action of Biceps.

In many of the changes of position of a body, whilst a bone is turning upon its centre of motion, the centre itself is often describing a curve at the same time. In Fig. 375, let A B represent the foot, B C the tibia, C D the thigh-bone, and D E the trunk; and let us suppose it is required to bring the body to the erect position B F; so that B C shall correspond to B G, C D to G I, and D E to I F. The point C will describe the curve C G; and, whilst it is accomplishing this, the point D is likewise moving; so that the latter, instead of describing the

Fig. 375.



Combined Muscular Movements in Rising.

curve D H, which it would do, were the centre of motion C fixed, proceeds along the curve D I: the point E, again, is subjected to the like influence; and instead of describing the curve E K, which it would do if the centre D were fixed, rises along E F.

The motions produced by the muscles may be either simple or compound. The simple muscles admit of variety; some being straight, composed of parallel fasciculi; others reflected in their course, and others, again, are circular. In the straight muscles, each fibre, by its contraction, draws the tendon in its own direction; and the effect of the whole is to bring it towards the centre of the muscle. In a long muscle, the whole contractile effort is concentrated on the tendon, in consequence of the course of the fibres being parallel to that of the tendon. In most of the broad muscles, on the other hand, as the attachments at both extremities are usually at different points, all the fibres do not concur in one effort. Different sets of fibres may have a very different action from others, and are capable of being thrown separately into contraction. The ordinary direction in which a muscle acts is from its tendinous, back to its aponeurotic, attachment,—that is, from the movable to the more fixed part; and, in a straight muscle, this direction can be accurately appreciated. It must be borne in mind, however, that the muscle can act in an inverse direction also.

When the whole of the fibres composing a broad muscle are brought to act on the tendon, as in the case of the deltoid, we find, by the composition of forces, that the middle line of direction must be taken for the purpose of estimating their line of action. A part, however, may act and carry the arm upwards and outwards; whilst the opposite fibres may move it upwards and inwards.

Where a muscle is reflected, like the superior oblique of the eye, and the peronei muscles,—the line of motion will be from the insertion to the point of reflection; precisely as a rope passing over a pulley raises the weight in a line drawn from the weight to the pulley.

The circular muscles, which have no precise origin or insertion, are inservient to the contraction of the apertures around which they are placed.

In executing the complex movements of any part of the frame, a combination of the action of the different muscles attached to the part, generally occurs,—rendering the process one of a complicated character. This, if no other cause existed, would render it extremely difficult to calculate the precise degree of force, which particular muscles, alone or in combination, are capable of exerting. The mathematical physiologists made multifarious attempts in this direction; but their conclusions were discrepant. When we bear in mind, that the force, capable of being exerted by any muscle, is dependent upon the proper organization of the muscle, and likewise upon the degree of energy of the brain, it will be apparent, that all attempts of the kind must be futile. We can determine with nicety the effect of which the parts are capable, supposing them inanimate structures. We can calculate the disadvantages, caused by the insertion of the power near the fulcrum; by the obliquity of the line of action of the power, &c.; but we have not the slightest data for estimating the effect produced by the nervous influx,—by that mysterious process, which generates a new

force, and infuses it into the muscles, in a manner so unlike that in which the ordinary mechanical powers are exerted. The data necessary for such a calculation would be the precise influx from the brain,—the irritability of the muscle,—the mechanical influences, dependent on the straight or oblique direction of the fibres composing it as regards the tendon,—the perpendicular or oblique direction in which the tendon is attached to the bone,—the particular variety of lever,—the length of the arm of the power and that of the resistance,—the loss sustained from friction, and the diminution of such loss caused by the cartilages that tip the bones, and by the synovia, &c.—data, which it is impossible to attain; and hence the solution of the problem is impracticable.

One great source of the combination of muscular motions is the necessity for rendering one of the attachments fixed, in order that the full force may be developed on the other. In but few of the muscles is the part, whence the muscle originates, steady. To these few, the muscles of the eye, which arise from the inner part of the orbit and pass forward to be inserted into the organ, belong. To show how distant muscles may be concerned in this fixation of one end of a muscle, when it is excited to the developement of plenary power, we may take the case of the deltoid, which arises from the scapula and clavicle, and is inserted into the os humeri: but the scapula and clavicle, themselves, are not entirely fixed; and, accordingly, if the deltoid were to contract alone, it would draw down the scapula and clavicle, as well as elevate the humerus. If, therefore, it be important to produce the latter effect only, the scapula and clavicle must be fixed by appropriate muscles; as by the rhomboidei, trapezius, &c. These muscles, however, arise from various vertebræ of the neck, which are themselves movable. It becomes necessary, therefore, that the neck should be fixed by its extensors, which arise from the lumbar and dorsal regions. By the united action of all these muscles, the deltoid is able to exert its full effect in elevating the humerus. But the deltoid, like other muscles, is capable of acting inversely; as in the case of a person lying on the ground, and attempting to raise himself by laying hold of any object above him. The hand and forearm are thus rendered firm, and the deltoid now contracts from origin to insertion, and, consequently, elevates the scapula and clavicle. Again, if a person, in the recumbent posture, endeavours to bend the head forwards, the recti muscles of the abdomen are firmly contracted for the purpose of fixing the sternum, whence the sterno-cleido-mastoidei muscles in part arise, which can then exert their full power in bending the neck forwards. These instances will be sufficient to exemplify the mode in which muscular motions are combined. The same principle prevails over the whole body; and where a greater number of parts has to be moved, the case must, necessarily, be more complex.

When a part, movable in various directions, is drawn towards any point, it must be rendered steady, and be prevented from deviating, by the muscles on each side; and the extent of its motion may be partly regulated by the action of antagonist muscles. Supposing, for instance, that the head is inclined forwards, there must be muscles not only to move it in that direction, but also to prevent it from inclining to the right or left, and to limit the motion forwards; although doubt

may arise, whether this be not entirely effected by the nervous influx sent by volition to the flexors of the head. Hence, some anatomists have considered, that there must, in these cases, be movers, directors, and moderators.

In sleep, the muscles are perhaps in the most complete state of relaxation; and, accordingly, this condition has been invoked, as affording evidence of the comparative preponderance of particular antagonizing muscles,—flexors and extensors, for example. In perfect sleep, when no volition is exercised over the muscles, the body reposes in a state of semiflexion,—which seems to show that the flexor muscles have slightly the advantage over the extensors. M. Richerand[1] has assigned the following reasons for this preponderance. *First.* The number of flexors is greater than that of extensors. *Secondly.* The fibres, composing them, are more numerous and longer:—take, for example, the sartorius, gracilis, semi-tendinosus, semi-membranosus, and biceps, which are flexors of the leg, and the rectus and triceps cruris, which are its extensors. *Thirdly.* Their insertion is nearer the resistance and farther from the centre of motion, which adds to their force. *Fourthly.* Their insertion into the bones is at a larger angle, and nearer the perpendicular; and *Fifthly.* Their arrangement is such, that the continuation of the movement of flexion renders them perpendicular to the bones to be moved. The explanation, afforded by M. Richerand, applies, on the whole, to the case he has selected; but there are many exceptions to it. The extensors of the thigh, foot, and jaw, are decidedly predominant; and, according to M. Adelon,[2] experiments, instituted by Regnier with his dynamometer, make the extensors some kilogrammes more powerful than the flexors. In our various attitudes, the movements of the flexors certainly prevail largely; but as the power of contraction is regulated by volition, it is unnecessary to inquire, whether there be any physical predominance in the flexors over the extensors, as has been attempted by M. Richerand. We have already seen, that we can in no way attain a knowledge of the degree of force, which any one muscle of the body is capable of developing.

TABLE OF THE MUSCLES,

ARRANGED AFTER THE MANNER OF DR. BARCLAY, ACCORDING TO THEIR ACTIONS.

THE HEAD IS MOVED

Forwards by	*Backwards by*	*To either side by*
Platysma myoides,	Part of trapezius,	Platysma myoides,
Sterno mastoideus,	Splenius capitis,	Sterno-mastoideus,
Rectus anticus major,	Complexus,	Part of trapezius,
" " minor,	Trachelo-mastoideus,	Splenius capitis,
	Rectus posticus major,	" colli,
Assisted (when the lower jaw is fixed) by	" " minor,	Trachelo-mastoideus,
	Obliquus capitis superior.	Complexus.
Mylo-hyoideus,		
Genio-hyoideus,		
Genio-hyo-glossus,		
Digastrici.		

[1] Recueil des Mémoires de la Société Médicale de Paris, an vii. (1799), and Élémens de Physiologie, 13ème édit., par M. Bérard, ainé; édit. Belge, p. 253, § clx., Bruxelles, 1837.

[2] Physiologie de l'Homme, 2de édit., ii. 117, Paris, 1829; and art. Dynamomètre, in Dict. des Sciences Médicales.

THE NECK IS MOVED

Forwards by

Platysma myoides,
Sterno-mastoideus,
Digastricus,
Mylo-hyoideus,
Genio-hyoideus,
Genio-hyo-glossus,
Omo-hyoidei,
Sterno-hyoidei,
Thyro-hyoidei,
Rectus anticus minor,
Longus colli.

Backwards by

Part of trapezius,
Rhomboideus minor,
Serratus posticus superior,
Splenius capitis,
" colli,
Complexus,
Trachelo-mastoideus,
Transversalis colli,
Inter-spinales colli,
Semi-spinales colli,
Rectus posticus major,
" " minor,
Obliquus capitis superior,
" " inferior,
Scaleni postici,
Levator scapulæ.

Laterally by

Various combinations of those muscles which separately move it forwards and backwards, assisted by the scaleni, inter-transversales, and recti-laterales.

THE TRUNK IS MOVED

Forwards by

Rectus abdominis,
Pyramidalis,
Obliquus externus abdominis,
Obliquus internus,
Psoas magnus,
" parvus,

Assisted (when the arms are carried forwards) by

Pectoralis major,
" minor,
Serratus magnus.

Backwards by

Trapezius,
Rhomboideus major,
Latissimus dorsi,
Serratus posticus superior,
" " inferior,
Sacro-lumbalis,
Longissimus dorsi,
Spinales dorsi,
Semi-spinales dorsi,
Multifidus spinæ,
Inter-transversales dorsi et lumborum.

Laterally by

Obliquus externus,
" internus,
Quadratus lumborum,
Longissimus dorsi,
Sacro-lumbalis,
Serrati postici,
Latissimus dorsi.

THE SCAPULA IS MOVED

Upwards by

Trapezius,
Levator scapulæ,
Rhomboidei.

Downwards by

Lower part of trapezius,
Latissimus dorsi,
Pectoralis minor.

Forwards by

Pectoralis minor,
Serratus magnus.

Backwards by

Part of trapezius,
Rhomboidei,
Latissimus dorsi.

THE HUMERUS IS MOVED

Forwards by

Part of deltoid,
Part of pectoralis major,

Assisted in some circumstances by

Biceps,
Coraco-brachialis.

Backwards by

Part of deltoid,
Teres major,
" minor,
Long head of triceps,
Latissimus dorsi.

Inwards by

Part of pectoralis major,
Latissimus dorsi.

Rotated inwards by

Subscapularis,

Assisted occasionally by

Pectoralis major,
Latissimus and teres major.

Outwards by

Supra-spinatus,
Infra-spinatus,
Teres minor.

THE FOREARM IS MOVED

Forwards by

Biceps,
Brachialis anticus,
Pronator teres,

Assisted by

Flexor carpi radialis,
" sublimis,
" ulnaris,
Supinator longus.

Backwards by

Triceps,
Anconeus.

Rotated inwards by

Pronator teres,
Flexor carpi radialis,
Palmaris longus,
Flexor sublimis,
Pronator quadratus.

Outwards by

Biceps,
Supinator brevis,
Extensor secundi internodii.

THE CARPUS IS MOVED

Forwards by	*Backwards by*	*Outwards by*	*Inwards by*
Flexor carpi radialis,	Extensor carpi radialis longior,	Flexor carpi radialis,	Flexor sublimis,
Palmaris longus,	Extensor carpi radialis brevior,	Extensor carpi radialis longior,	" carpi ulnaris,
Flexor sublimis,	Extensor secundi internodii,	Extensor carpi radialis brevior,	" profundus,
" carpi ulnaris,	Indicator,	Extensor ossis metacarpi,	Extensor communis digitorum,
" profundus,	Extensor communis digitorum,	Extensor primi internodii.	Extensor minimi digiti,
" longus pollicis.	Extensor proprius pollicis.		Extensor carpi ulnaris.

THE THUMB IS MOVED

Inwards and forwards, across the palm, by	*Outwards and backwards by*	*Upwards and forwards, away from the other fingers, by*	*Backwards and inwards, to the other fingers, by*
Opponens pollicis,	Extensor ossis metacarpi pollicis,	Abductor,	Adductor,
Flexor brevis,	Extensor primi internodii,	*Assisted by part of the* Flexor brevis.	Extensor primi internodii.
" longus.	Extensor secundi internodii.		Extensor secundi internodii.

THE FINGERS ARE MOVED

Forwards, or flexed, by	*Backwards, or extended, by*	*Outwards, to radial border, by*	*Inwards by*
Flexor sublimis,	Extensor communis,	Abductor indicis,	Abductor digiti minimi,
" profundus,	" minimi digiti,	" digiti minimi,	Interossei.
Lumbricales,	Indicator.	Interossei.	
Interossei,			
Flexor brevis digiti minimi,			
Abductor digiti minimi.			

THE THIGH IS MOVED

Forwards by	*Backwards by*	*Inwards by*	*Outwards by*
Psoas magnus,	Gluteus maximus,	Psoas magnus,	Tensor vaginæ femoris,
Iliacus,	Part of gluteus medius,	Iliacus,	Gluteus maximus,
Tensor vaginæ femoris,	Pyriformis,	Pectineus,	" medius,
Pectineus,	Obturator internus,	Gracilis,	" minimus,
Adductor longus,	Part of adductor magnus,	Adductor longus,	Pyriformis.
" brevis.	Long head of biceps,	" brevis,	
	Semi-tendinosus,	" magnus,	
	Semi-membranosus.	Obturator externus,	
		Quadratus femoris.	

THE THIGH IS ROTATED

Inwards by	*Outwards by*
Tensor vaginæ femoris,	Gluteus maximus,
Part of gluteus medius,	Part of gluteus medius,
	Pyriformis,
And, when the leg is extended, by	Gemellus superior,
Sartorius,	Obturator internus,
Semi-tendinosus.	Gemellus inferior,
	Quadratus femoris,
	Obturator externus,
	Psoas magnus,
	Iliacus,
	Adductor longus,
	" brevis,
	" magnus,
	Biceps cruris, slightly.

THE LEG IS MOVED

Backwards, or flexed, by	*Extended by*
Semi-tendinosus,	Rectus,
Biceps,	Crureus,
Semi-membranosus,	Vastus externus,
Gracilis	" internus.
Sartorius,	
Popliteus.	

THE FOOT IS MOVED

Forwards, or flexed, by	*Backwards, or extended, by*	*Inclined inwards by*	*Outwards by*
Tibialis anticus,	Gastrocnemius,	Extensor proprius pollicis,	Peroneus longus,
Extensor proprius pollicis,	Plantaris,	Flexor longus digitorum,	" brevis,
Extensor longus digitorum,	Soleus,	Flexor longus pollicis,	Extensor longus digitorum,
Peroneus tertius.	Flexor longus digitorum,	Tibialis posticus.	Peroneus tertius.
	Flexor longus pollicis,		
	Tibialis posticus,		
	Peroneus longus,		
	" brevis.		

THE TOES ARE MOVED

Backwards, or flexed, by	*Forwards, or extended, by*	*Inclined inwards by*	*Outwards by*
Abductor pollicis,	Extensor longus digitorum,	Abductor pollicis,	Adductor pollicis,
Flexor brevis digitorum,	Extensor proprius pollicis,	Interossei.	" digiti minimi,
Abductor minimi digiti,	Extensor brevis digitorum.		Interossei.[1]
Flexor longus pollicis,			
" digitorum,			
" accessorius,			
Lumbricales,			
Flexor brevis pollicis,			
Adductor pollicis,			
Flexor brevis minimi digiti,			
Interossei.			

3. ATTITUDES.

The attitudes, which man is capable of assuming, are of different kinds. They may, however, be reduced to two classes—the *active* and the *passive;* the former including those that require a muscular effort; and the latter comprising only one variety,—that in which the body is extended horizontally on the soil, and no effort needed to maintain its position.

We shall begin with the most ordinary attitude;—that of *standing on both feet.* This requires considerable muscular effort to preserve equilibrium. The base of sustentation—the space comprised between the feet plus that occupied by the feet themselves—is small; whilst the centre of gravity is high. The body, again, does not consist simply of one bone, but of many; all of which have to be kept steady by muscular effort; and it is necessary, that the vertical line shall fall within the base of sustentation, in order that equilibrium may be preserved.

That standing is the effect of the action of the different extensors is proved by the fact, that if an animal be killed suddenly, or stunned, so

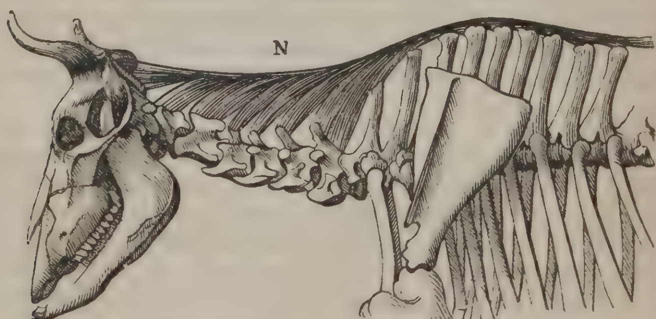
[1] Quain's Human Anatomy, by Quain and Sharpey, Amer. edit. by Leidy, i. 465, Philadelphia, 1849.

that volition is no longer exerted over the extensors, it immediately falls forward.

The head, which is intimately united with the atlas or first vertebra of the neck, forms with it a lever of the first kind; the fulcrum being in the articulation of the lateral parts of the atlas and vertebra dentata; whilst the power and the resistance occupy the extremities of the lever; and are situate—the one at the face, the other at the occiput. The fulcrum being nearer the occiput than to the anterior part of the face, the head has a tendency to fall forwards. This can be readily seen by supporting a skull on the condyles; yet Mr. Abernethy[1] affirms, that "the condyles are placed so exactly parallel in the centre of gravity, that when we sit upright, and go to sleep in that posture, the weight of the head has a tendency to *preponderate equally* in every direction, as we see in those who are dozing in a carriage"! In the living subject, the preponderance anteriorly is not so great as it is in the skeleton, because the greater part of the encephalon is lodged in the posterior portion; but the fact, that when we go to sleep in the upright position the head drops forward is sufficient evidence that it exists; and that in the waking state the head is kept in equilibrium on the vertebral column by the contraction of the extensor muscles of the head, which are situate at the back part of the neck, and inserted into the head;—as the splenius, complexus, trapezius, and posterior recti. These muscles are inserted perpendicularly into the lever or bone to be moved,—an advantage, and some compensation for the shortness of the arm of the lever by which they act.

In quadrupeds, the head not being in equilibrium on the spine, these muscles are large and strong; the spinous and transverse processes of the vertebræ and the occipital depressions are larger; and, in addition, they have a strong ligament—*posterior cervical* or *ligamentum nuchæ*, (N, Fig. 376),—which extends from the spinous processes of the vertebræ to the occiput, and aids in supporting the head.

Fig. 376.



Ligamentum Nuchæ.

The vertebral column supports the head, and transmits the weight to its lower extremity. The tendency of the column is to bear for-

[1] Physiological Lectures, exhibiting a general view of Mr. Hunter's Physiology, &c., Lect 3, 2d edit., p. 115, London, 1822.

wards;—the upper limbs, neck, thorax with its contents, the greater part of the contents of the abdomen, and the head itself, by reason of its tendency to fall forwards, either directly or indirectly exert their weight upon it. Hence the necessity for its great firmness and solidity, which are readily appreciated, if we examine the mode of junction of the different vertebræ, with the strong, ligamentous bands connecting them, the whole having the form of a pyramid, whose base rests upon the sacrum, with three curvatures in opposite directions, which give it more resistance than if it were straight, and enable it to support very heavy burdens in addition to the weight of the organs pressing upon it. The tendency of the spine to fall forward is resisted by the extensor muscles, which fill the vertebral fossæ or gutters—sacro-lumbalis, longissimus dorsi, multifidus spinæ, &c.—and pass from the sacrum to the lower vertebræ of the spine, and from the lower to the upper. Each vertebra, in this action, constitutes a lever of the first kind; the fulcrum of which is in the intervertebral cartilage; the power in the ribs, and other parts that draw the body forwards; and the resistance in the muscles attached to the spinous and transverse processes.

Fig. 377.

Lateral View of a Dorsal Vertebra.

1. Body. 6. Spinous process. 7. Extremity of transverse process. 8. Superior articular processes. 9. Inferior articular processes.

The vertebral column, regarded as a whole, may be considered a lever of the third kind; the fulcrum of which is in the union between the last lumbar vertebra and sacrum, the power in the parts drawing the spine forward, and the resistance in the muscles of the back. It is on the lower part of the lever that the power acts most forcibly; and it is there that the pyramid is thicker, and that the spinous and transverse processes are larger, and more horizontal. We can accordingly comprehend why fatigue should be experienced in the loins and sacrum, when we have been, for a long time, in the erect attitude. It need scarcely be said, that the longer and more horizontal the spinous processes, the greater will be the arm of the lever; and the less the muscular force necessary to produce a given effect.

Fig. 378.

Lateral View of a Lumbar Vertebra.

1. Body. 5. Spinous process. 6. Transverse process. 7. Superior articular processes. 8. Inferior articular processes.

The weight of the whole of the upper part of the body is transmitted to the pelvis; which, resting upon the thigh-bones as on pivots, represents a lever of the first kind, the fulcrum being in the ilio-femoral articulations; the power and resistance situate before and behind. The pelvis supports the weight of a part of the abdominal viscera; and the sacrum that of the vertebral column, which, by reason of its shape, transmits the weight equally to the ossa femorum, through the medium of the ossa ilii. When the pelvis is, therefore, in equilibrium on the heads of the thigh-bones, this is owing

to many causes. The abdominal viscera, pressing upon the anterior part of the pelvis, which is naturally inclined forwards, tend to depress the os pubis; whilst the vertebral column by its weight tends to press down the sacrum. As the weight of the latter is more considerable than that of the former, muscles would seem to be required to keep it in equilibrium, as well as others passing from the femur to be inserted into the os pubis, by the contraction of which the excess of weight of the vertebral column may be counterbalanced. Such muscles do exist; but, as M. Magendie[1] remarks, they are not the great agents in producing the equilibrium of the pelvis on the thigh-bones; for the pelvis, instead of having a tendency to be depressed posteriorly, would appear to bear forwards, inasmuch as the muscles, that resist the tendency which the spine itself has to bear forwards, have their fixed point on the pelvis; and consequently exert a considerable effort to draw it upwards. The strong glutæi muscles, which form the nates, and are inserted into the os femoris, are the great agents of the equipoise; and as the hip-joint is nearer the pubis than it is to the sacrum, these muscles act with a greater leverage.

The thigh-bones transmit the weight of the trunk to the tibia; and here we see the advantage of the neck of the thigh-bone, which, as represented in Fig. 379, B, joins the shaft at a considerable angle. The trochanters D and C are for muscular attachments; and are, of course, advantageous to the muscles, which are inserted into them. The cervix femoris directs the head of the bone, A, obliquely upwards and inwards, so that, whilst it supports the vertical pressure of the pelvis, it resists the separation of the ilia, which the pressure of the sacrum, with its superincumbent weight, has a tendency to produce.

Fig. 379.

Upper Portion of Thigh-Bone.

But another and important advantage is that of affording additional strength in adventitious circumstances. When we are standing perfectly erect, the necks of the thigh-bones are very oblique, compared with the line of direction of the body; but if we are thrown forcibly to one side, the line of direction of gravitation corresponds more nearly with that of the neck of the thigh-bone, and fracture is rarely produced in this manner. The most common cause of fracture of the neck of the thigh-bone is slipping, with one foot, from a curbstone, or any slight elevation, upon a firm substance beneath; and the fracture in such case, is generally transverse. The advantage of this arrangement of the neck of the thigh-bone has been compared not inaptly to that resulting from the *dishing* of a wheel; or the oblique position of the spokes from the nave outward to the felly, which strengthens the wheel against the strains produced by its sinking with force into a rut or other hollow.[2] The femur transmits the weight of the body to the large bone of the leg—the tibia; but, from the

[1] Précis, &c., edit. cit., i. 296.

[2] See Fig. 357; also, Sir C. Bell, Animal Mechanics, p. 21, Library of Useful Knowledge, Lond., 1829.

mode in which the pelvis presses upon it, its lower extremity has a tendency to bear forwards. This is prevented by the action of the extensors of the leg—rectus and triceps cruris—whose power is augmented by the presence of the patella—a sesamoid bone, seated behind their tendon. The muscles of the posterior part of the leg, which are attached to the condyles of the thigh-bone, aid also in preserving the equilibrium.

The tibia is the sole agent for the transmission of the superincumbent weight to the foot. Its upper extremity has, however, a tendency to bear forwards like the lower part of the os femoris. This is prevented by the contraction of the gastrocnemii, tibialis posticus, and other muscles on the posterior part of the leg.

The foot sustains the whole weight of the body; and its shape and structure are well adapted for the purpose. The sole has some extent, which contributes to the firmness of the erect attitude. The skin and epidermis are thick; and beneath the skin is a thick, adipous stratum, in greater quantity at the parts of the foot which come in contact with the soil. This fat forms a kind of elastic cushion, adapted for deadening or diminishing the effect of pressure. The whole of the sole of the foot does not come in contact with the ground. The weight is transmitted by the heel, the outer margin, the part corresponding to the anterior extremity of the metatarsal bones, and the extremities or pulps of the toes. The tibia transmits the weight to the astragalus; and from this bone it is distributed to the others that compose the foot; but the heel conveys the largest share. When the foot rests upon a flat surface, it is entirely passive; but when upon a slippery soil, the flexors of the toes, especially of the great toe, are firmly contracted, so as to fix the shoe, as far as possible, and render the attitude more stable. The use of shoes interferes largely with the exercise of the toes, which, in the savage, are capable of diversified and considerable action.

The use of the fibula is, to serve the purpose of a clasp, as its name imports. The tibia exerts its pressure chiefly towards the inner part of the foot, and, consequently, were it not for the fibula, which passes down below the articulation, dislocation outwards would be constantly menacing us. The fibula has no participation in the transmission of the weight to the ground.

The conditions for equilibrium, as applicable to man, have been already indicated. If the base of sustentation be rendered extensive in any one direction, as by widely separating the feet, the attitude is more firm in one direction, but less so in the other. It is as firm as possible in every direction, when the feet are turned forwards parallel to each other, and are separated by a space equal to the length of one. Whatever diminishes the base of sustentation diminishes, in like proportion, the stability of the erect attitude. Hence the difficulty of walking on stilts or wooden legs, on the toes, tight rope, &c. It seems that the inhabitants of Les Landes,[1] in the south-west of France, are enabled by habit to use stilts with singular facility. The sandy plains, that bear this name, afford tolerable pasturage for sheep; but, during

[1] Arnott, Elements of Physics, 3d Amer. edit., i. 15, Philad., 1835.

one part of the year, they are half covered with water; and during the remainder, they are very unfit walking ground, on account of the deep, loose sand, and thick furze. The natives, in consequence, habituate themselves to the use of stilts or wooden poles, the former of which are put on and off as regularly as parts of their dress. With these they walk readily over the loose sand or through the water, with steps eight or ten feet long. The difficulty, in this kind of progression, does not arise solely from the smallness of the base of sustentation, but from the greater height to which the centre of gravity is thrown, which renders the equilibrium unstable.

Standing on one foot is necessarily more fatiguing, as it requires the strong and sustained contraction of the muscles that surround the hip-joint, to keep the pelvis in equilibrium on the os femoris; especially as the body has a strong tendency to fall to the side that is unsupported. The muscles, that prevent the trunk from falling in this direction, are the glutæi, gemelli, tensor vaginæ femoris, pyramidalis, obturators, and quadratus femoris. The use of the neck of the thigh-bone and the great trochanter is here manifest. The base of sustentation, in this case, is the space occupied by the foot which is in contact with the soil; and it need hardly be said, that if this be still farther diminished, by attempting to stand on the toes, the attitude cannot be sustained.

In the *attitude on the knees*, the centre of gravity is brought lower, but the base of sustentation is smaller than on the feet. The patella has to bear the chief pressure, and as it is not provided with a fatty cushion such as exists at the sole of the foot, the position becomes painful, and the surface soon abraded. These remarks apply to the case, in which the knees only come in contact with the soil. When the feet are allowed to touch also, by the points of the toes, the attitude is much more easy and firm, as the base of sustentation is largely augmented, and comprises the space between the knees and toes plus the space occupied by those parts.

The *sitting posture* admits of variety, and its physiology is easily intelligible. In every form in which the back is unsupported, the weight of the body is conveyed to the soil by the pelvis; and the broader this base the firmer the attitude. When we sit upon a stool without any back, and with the legs raised from the ground, the whole of the weight is conveyed by the parts in contact with the seat; but if the feet touch the ground, the weight of the lower extremities is transmitted to the soil by the feet, whilst the pelvis transmits that of the upper part of the body. In both cases, if the attitude be long maintained, fatigue is felt in the back, owing to the continued action of the extensor muscles in keeping the body erect. Sitting in an ordinary chair differs somewhat, in a part of the body being supported. Fatigue is felt in the neck, which is unsupported, and requires the sustained contraction of the extensor muscles of the head. To support all the parts, as far as possible, long-backed chairs have been introduced, which sustain the whole body and head; and, when they are provided with rockers, a position approaching to the easiest of all attitudes can be assumed. To produce a similar effect in a common chair, the body is often thrown back until the chair rests on its hinder legs

only. When the feet of the individual are on the ground, this position is stable; the base of sustentation being large, and comprised between the legs of the chair and the feet of the individual, added to the space occupied by the parts themselves, that are in contact with the soil; but as soon as he raises his feet, the equilibrium is destroyed from the impracticability of making the vertical line fall within the base of sustentation, which is now reduced to the space occupied by the legs of the chair plus the space between them. In all the varieties of the sitting posture, equilibrium is facilitated by the centre of gravity being brought nearer to the ground.

Lastly. The *horizontal posture* is the only one that requires no muscular effort. Hence it is the attitude of repose, and of the sick and the feeble. The base of sustentation is here extremely large; and the centre of gravity very low. Accordingly, the attitude can be maintained for a long time; the only inconvenience being that which results to the skin from prolonged pressure on those parts that chiefly convey the weight to the bed,—as the back of the pelvis, the region of the great trochanter, &c.—an inconvenience, which attracts the attention of the physician, more or less, in all protracted and consuming maladies. The reason, why we prefer soft, elastic beds, is not simply to prevent abrasion of those parts of the body that are most exposed to pressure, but to enable a greater portion of the body to transmit the weight; and thus occasion a more equable partition of the pressure.

There are numerous other attitudes, which may be assumed; as, upon one knee, on the head, astride, &c.; but they do not need explanation,—their physiology being obvious after what has been said.

4. MOVEMENTS.

The movements, of which the body is susceptible, are of two kinds,—*partial* and *locomotive;* the former simply changing the relative situation of parts of the body; the latter the relation of the whole body to the soil. Many of the partial movements constitute an inherent part of the different functions, and are considered under them.

In the erect attitude, whilst the body holds the same correspondence with the soil, the position of the upper parts of the body may be greatly varied, provided the vertical line falls within the base of sustentation. Accordingly, to produce this effect, if the upper part of the body be inclined in one direction, the lower will have to be thrown more to the opposite.

The head may be turned forwards, backwards, or to one side; and it is capable of a rotatory motion to the right and left. The first three movements, when slight, occur in the articulation of the occipital bone and atlas; but if to a greater extent, the whole of the cervical vertebræ participate. The rotatory motion is effected essentially in the articulation between the first and second vertebræ; the latter of which has an arrangement admirably adapting it for this purpose. A toothlike or *odontoid* process arises from its anterior part, on which the posterior surface of the anterior part of the atlas or first vertebra turns as on a pivot. This arrangement has obtained the second vertebra the name *vertebra dentata*, and its function, that of *axis.* Rotation to the right is

effected by the contraction of the left sterno-mastoid and splenius, and of the right complexus,—to the left by the action of the opposite muscles of the same name. The motions of the head aid the senses of sight, hearing, and smell; and are useful in the production of the different vocal tones, by occasioning elongation or decurtation of the trachea and vocal tube. They are, likewise, inservient to expression.

The spine, as a whole, and each of the vertebræ composing it, are capable of flexion, extension, lateral inclination, and circumduction. These motions occur in the fibro-cartilages between the vertebræ; and they are more easy and extensive, in proportion to the thickness and width of the cartilages. This is one cause why the motions of the cervical and lumbar portions of the vertebral column are freer than those of the dorsal. The *intervertebral substances* or *fibro-cartilages* possess a remarkable degree of elasticity. They yield somewhat, however, to prolonged pressure; and hence, after long continuance in the erect attitude, our stature may be sensibly curtailed. We can thus understand, that at night we may be shorter than in the morning. Buffon asserts, that the son of one of his most zealous *collaborateurs*, M. Guéneau de Montbeillard,—a young man of tall stature,—lost an inch and a half after having danced all night. The loss must be partly ascribed to the condensation of the adipous tissue beneath the foot. During the flexion of the spine, these cartilages are depressed on the side of the flexure, but they rise on the other; and, by their elasticity, are important agents in the restoration of the body to the erect position. Where they are thickest the greatest extent of motion is permitted, and this is a cause why the spine admits of the greatest motion anteriorly. In rotation, the whole is pressed upon and undergoes elongation in the direction of its constituent laminæ. In old age, the cartilages become shrivelled; and this, with the loss of muscular power, is one of the causes why old people bend forwards.

When we assume different positions with the trunk, the centre of motion of the vertebræ becomes modified. If we bend forwards, it is thrown on the anterior part of the body of the vertebræ; if to one side, on the articulating processes, &c. Each vertebra, we have seen, is a lever of the first kind; and as the centre of motion becomes altered the leverage must be so likewise. It is when the body has been bent forwards, and the object is to restore it to the erect position, that the power acts with the greatest advantage,—the fulcrum being thrown to the anterior part of the body of the vertebra, and the arm of the power being the distance between this point and the extremity of the spinous process into which the power is inserted.

Each vertebra has but a slight degree of motion; but the sum of all their motions is considerable, and is estimated by multiplying the single motion by the number of vertebræ. The result, however, can only be regarded as approximate, as the extent of motion, of which the different vertebræ are capable, necessarily varies. The arrangement of the spinous processes of the vertebræ—especially of the *dorsal*—prevents any considerable flexion of the body backwards; and when we find the tumbler bending his body back until his head touches his heels, it is owing to the arrangement of the spine having been modified in early life by constant efforts of the kind, until there are no longer obstacles to the movement.

The motions of the vertebræ are frequently united to those of the pelvis on the thigh-bones, so that they seem to be more extensive than they really are. This is the case when we make a low bow.

The motions of the spine are inservient to those of the head, and of the superior and inferior extremities.

The upper limbs are capable of various motions; some of which have been already described; others will be hereafter. They are useful in the different attitudes; and, at times, by transmitting to the soil a part of the weight of the body, and thus enlarging the base of sustentation, —as when we employ a stick, rest on the hands and knees, or support the head on one or both elbows. They are of great use, likewise, in preserving equilibrium when we walk on a very narrow base; serving in part the purpose of the pole employed by the dancer on the tight-rope.

The lower extremities are, of course, locomotive organs; but they are susceptible of partial movements likewise; as when we kick with one foot, try the consistence of the ground, cross the legs, tread the foot-board of a lathe, &c.

Thus much for the attitudes. We shall now consider the mode in which the relation of the body to the soil is altered, comprising the physiology of walking, leaping, running, swimming, flying, &c., which constitute the different varieties of locomotion or progression.

a. LOCOMOTIVE MOVEMENTS.[1]

a. *Walking.*

Walking is motion on a fixed surface, the centre of gravity being alternately moved by one of the extremities and sustained by the other, without the latter being, at any time, completely off the ground. It consists of a succession of steps, which are effected—in the erect attitude and on a horizontal surface—by bending one of the thighs upon the pelvis and the leg upon the thigh, so as to detach the foot from the ground by the general decurtation of the limb. The flexion of the limb is succeeded by its being carried forward; the heel is then brought to the ground, and, successively, the whole of the inferior surface of the foot. If the bones of the leg were perpendicular to the part which first touches the ground, we should experience a jolt; but, instead of that, the foot descends in an arc of a circle, the centre of which is the point of the heel.

Fig. 380.

Movement of the Foot in Walking.

In order that the limb shall be thus carried forward, the pelvis must have described a movement of rotation on the head of the thigh-bone of the limb that has not been moved, and must have carried forward the corresponding side of the body. As yet,

[1] On the whole subject of Animal Motion, Animal Dynamics, Locomotion, or Progressive Motion of Animals, see an elaborate article by J. Bishop, in Cyclopædia of Anatomy and Physiology, Part xxiii. p. 407, London, April, 1842, and Prof. E. Weber, Art. Muskelbewegung, in Wagner's Handwörterbuch der Physiologie, 15te Lieferung, S. 1, Braunschweig, 1846.

only one limb has advanced. The base of sustentation has been modified, but there has been no progression. The limb, remaining behind, has now to be raised and brought forward, so as to pass the other, or to be on the same line with it, as the case may be; and this finishes the *step*. In order to bring up the limb that is behind, the foot must be successively detached from the soil, from the heel to the toe. In this way, an elongation of the limb is produced, which assists in advancing the corresponding side of the trunk, and excites the rotation of the pelvis on the head of the thigh-bone first carried forward. A succession of these movements constitutes walking; the essence of which consists in the heads of the thigh-bones forming fixed points, on which the pelvis turns alternately, as upon a pivot, describing arcs of circles, which are more extensive in proportion to the size of the steps.

Walking in a straight line requires that the arcs of circles described by the pelvis, and the extension of the limbs when carried forward, shall be equal; otherwise, the body will be directed towards the side opposite to that of the limb whose movements are more extensive. Without the aid of vision, it would be impracticable for us to make the arcs equal, or to walk straight forward.

Walking backwards differs somewhat from this. The step is commenced by bending the thigh upon the pelvis, and, at the same time, the leg upon the thigh. The extension of the thigh on the pelvis succeeds, and the whole limb is carried backward; the leg is afterwards extended upon the thigh, the point of the foot is brought to the ground, and the remainder of its under surface in succession. The other foot is then raised on its point, by which the corresponding limb is elongated; the pelvis, being pushed backwards, makes a rotation on the limb which is behind, and is, by the action of appropriate muscles, carried on a level with, or behind, the other, to afford a new pivot in its turn. Walking laterally is different from the two last in no arcs being described. In this case, one of the thighs is first slightly bent upon the pelvis, in order to detach the foot from the ground; the whole limb is then moved away by the action of the abductors, and is brought down to the ground. The other limb follows.

If we walk up hill, the fatigue is much augmented; because the flexion of the limb, first carried forward, has to be more considerable; and the limb, that remains behind, has not only to cause the pelvis to execute the movement of rotation, but it has to raise the whole weight of the body, in order to transport it upon the limb which is in advance. To aid in throwing the weight forward, the body is bent forward, so that the centre of gravity may be as favourably disposed as possible; and the extensor muscles of the leg carried forward are powerfully contracted to raise the trunk; hence, the feeling of fatigue, which we experience in the knee and anterior part of the thigh, on ascending a long flight of stairs. Fatigue is likewise felt in the calf of the leg, on account of the strong efforts developed in extending the foot, and projecting the body forward. Walking down hill is more fatiguing than on level ground. In this case, there is a tendency in the body to fall forward; great effort is, consequently, required to keep the vertical line within the base of sustentation; and, accordingly, the muscles,

employed in the extension of the head and vertebral column, experience fatigue.

In all these kinds of progression, the character of the soil is a matter of importance. It must be firm enough to afford support to the limb that presses upon it, otherwise fatigue is experienced, and progression is slow and laborious. This occurs, whenever the soil is too soft or too smooth; the former yielding to the foot, and the latter presenting no inequalities to which the foot can attach itself. The soil, too, has some influence, in particular cases, by virtue of its elasticity. Such, at least, is the opinion of Borelli;[1] but Barthez[2] thinks, that the influence of the soil is limited to the degree in which it furnishes a firm support. If the soil, again, be movable, as the deck of a vessel, the line of gravity is apt to fall outside the base of sustentation; and to avoid this, the base is enlarged by separating the legs so as to give a characteristic air to the gait of the mariner;—and, lastly, if the base be very narrow, as on the tight-rope, the steps are obliged to be rapid, and the arms are aided in modifying the centre of gravity as may be required, by the use of a long and heavy pole.

b. *Leaping.*

In the action of leaping, the whole body is raised from the ground; and, for a short period, suspended in the air. It consists, essentially, in the sudden extension of the limbs, after they have undergone an unusual degree of flexion. Leaping may be effected directly upwards, forwards, backwards, or laterally.

In the ordinary case of the vertical leap, the head is slightly bent on the neck; the vertebral column curved forwards; the pelvis bent upon the thigh; the thigh upon the leg; and the leg upon the foot; the heel generally pressing lightly on the soil, or not touching it at all. This state of general flexion is suddenly succeeded by a quick extension of all the bent joints; so that the different parts of the body are rapidly elevated, with a force surpassing their own gravity, and to an extent dependent upon the force developed. In this general muscular movement, the muscles that form the calf of the leg, and are inserted into the heel, have to develope the greatest force, inasmuch as they have to raise the whole body, and to give it the impulse, which surmounts its gravity. They are, however, favourably circumstanced for the purpose;—being remarkably strong; inserted perpendicularly into the heel; and having the advantage of a long arm of a lever. Figure 375 will show, that whenever the body is bent in the position it assumes preliminary to a leap, opposite impulses must be communicated by the restoration of the different parts to the vertical line B F. The leg B will tend to impel the body backwards, by following the curved line C G. C D, on the other hand, by describing the curve D I, will tend to impel it forward; whilst the head and trunk, represented by the line D E, will describe the curve E F, and give an impulse backward. Every vertical leap must, therefore, be a mean between these different impulses; or rather the backward and forward impulses must destroy

[1] De Motu Animalium, &c., Lugd. Bat., 1710.

[2] Nouveaux Elémens de la Science de l'Homme, Paris, 1806.

or neutralize each other; and that which is concerned in the elevation of the trunk be alone effective.

In the forward leap, the movement of rotation of the thigh predominates over the impulses backward, and the body is projected forward. On the other hand, the impulses of the vertebral column, and of the leg on the foot, prevail in the backward leap. The length of the lower limbs is favourable to the extent of the leap. The forward leap, in particular, is greatly dependent upon the length of the femur, in which the forward impulse is situate. It does not appear, that any kind of impulse is communicated to the body, at the moment of leaping, by the surface on which we rest, unless it be very elastic. In this last case, however, its reaction is added to the effort of the muscles, that occasion the elevation of the body; hence, the wonderful leaps of the performers in circuses and on the tight-rope. On the other hand, if the soil does not afford the necessary resistance, and yields to the feet, leaping is almost or wholly impracticable.

The upper extremities are not without their use in leaping. They are brought close to the body, whilst the joints are bent, and are separated from it at the moment when the body leaves the ground. By being held firmly in this manner, they allow the muscles, that pass from the os humeri to the trunk, to exert a degree of traction upwards, and thus to assist the extensors of the feet in the projection of the body. It is with this view, that the ancients employed their ἁλτηρες or *poisers* in leaping; and that the moderns use bricks, stones, or other solid heavy bodies with a like intent. It is likewise manifest, that by steadying the arms, and then moving them rapidly backwards, a backward impulse may be given to the upper part of the trunk.

The effect of a run before we leap is to add to the force developed by muscular contraction that of the impulse acquired by the body whilst running. The leap is, under such circumstances, necessarily more extensive.

Some of the smaller animals surprise us by the extent of their leaps. The *jumping maggot*, found in cheese, erects itself upon its anus, forms its body into a circle, by bringing its head and tail into contact, and, having contracted every part as much as possible, unbends with a sudden jerk, and darts forward to an astonishing distance. Small animals leap much farther than the larger in proportion to their size; and, as Mr. Sharon Turner has remarked,[1] "exhibit muscular powers still more superior to those of the greatest animals than their comparative minds." He has given amusing representations of this difference: for example, Linnæus observes, that if an elephant were as strong in proportion as a stag beetle, he would be able to tear up rocks and level mountains. A cock-chafer is, for its size, six times as strong as a horse.[2] The flea and locust leap two hundred times their own length, as if a man should leap three times as high as St. Paul's.[3] The cuckoo-spit froghopper sometimes leaps two or three yards, which is more than two hundred and fifty times its own length, as if a man

[1] Sacred History of the World, Amer. edit., p. 372, New York, 1832.
[2] Kirby and Spence, Introduction to Entomology, Amer. edit., p. 486, Philad., 1846.
[3] Nat. History of Insects, i. 17.

should vault at once a quarter of a mile.[1] Mouffet[2] relates, that an English mechanic made a golden chain as long as a finger, with a lock and key, which was dragged by a flea; and Latreille[3] mentions a flea of moderate size dragging a silver cannon on wheels, that was twenty-four times its own weight. This cannon was charged with powder and fired, without the flea seeming to be alarmed.

c. *Running.*

This variety of progression consists of a series of low leaps performed by each leg in alternation. It differs from walking, in the body being projected forward at each step, and in the hind-foot being raised before the fore-foot touches the ground. It is more rapid than the quickest walk, because the acquired velocity is preserved and increased, at each bound, by a new velocity. Running, therefore, cannot be instantaneously suspended, although a stop may be put to walking at any moment.

In running, the body is inclined forward, in order that the centre of gravity may be in a proper position for receiving an impulse in that direction from the hind-leg; and the fore-leg is rapidly advanced to keep the vertical line within the base of sustentation, and thus prevent the body from falling. There is, consequently, in running, a moment in which the body is suspended in the air.

d. *Swimming.*

Although M. Magendie[4] affirms that the human body is, in general, specifically heavier than water; and that consequently, if left to itself in a considerable quantity of that fluid, it would sink to its lowest portion, the question respecting its specific gravity has not been rigorously determined; and many eminent practical philosophers have even held an opinion the reverse of that of Magendie. Borelli[5] accords with him; and a writer of a later period, Mr. Robertson,[6] who details a set of experiments on this subject, seems to have originally coincided with him also. He weighed, however, ten different individuals in water, comparing the weight with that of the fluid displaced by their bodies; and he affirms, that, with the exception of two, every man was lighter than his equal bulk of water, and much more so than his equal bulk of sea water;—"consequently," he says, "could persons, who fall into water, have presence of mind enough to avoid the fright usual on such accidents, many might be preserved from drowning." In corroboration of this inference, Mr. Robertson relates a circumstance connected with his own personal knowledge. A young gentleman, thirteen years of age, little acquainted with swimming, fell overboard from a vessel in a stormy sea; but having had presence of mind enough to turn immediately upon his back, he remained a full half hour, quietly floating on the surface of the water, until a boat was

[1] Insect Transformations, v. 6, p. 179.
[2] Theatr. Insect., 275.
[3] Nouv. Dict. d'Histoire Natur., xxviii. 249, and Kirby, op. cit.
[4] Précis Élémentaire, i. 333.
[5] De Motu Animalium, c. 23, de Natat. Prop., 217.
[6] Philos. Transact., vol. l.; also, Dr. Dalton, in Manchester Memoirs, vol. x.

lowered from the vessel. He had used the precaution to retain his breath whenever a wave broke over him, until he again emerged.

A case is given in the Rev. Mr. Maude's *Visit to Niagara* in 1803, which is corroborative of Mr. Robertson's view of this matter. The author was on board a sloop on Lake Champlain, when a boy, named Catlin, who was on deck cutting bread and cheese with a knife. was knocked overboard by the captain jibbing the boom. He missed catching hold of the canoe, which was dragging astern, and an attempt of Mr. Maude's servant to untie or cut the rope, which fastened it, that it might drift to his assistance, also failed. Catlin was known to be unable to swim. It was in the night and very dark, and it was with difficulty that the captain, who considered that there was no hope of saving his life, was at last prevailed upon to go in the canoe to attempt it. He succeeded, however, in picking the boy up, and brought him on board again in about a quarter of an hour. "Catlin's relation," proceeds Mr. Maude, "almost exceeds probability. He had heard my exclamation to seize the canoe, which he was on the point of doing, when it gave a sudden swing and baffled him; but, finding he could support his head above water, he dismissed all fear, expecting that the canoe would come every moment to his assistance. When he no longer heard our cheers from the sloop, hope began to fail him, and he was on the point of resigning himself to a watery grave, when he heard the captain's life-restoring voice. On telling Catlin that we despaired of his safety, as we understood that he could not swim, he replied: 'Nor can I. I was never before out of my depth; but I am fond of bathing, and have often seen lads what they call tread the water; that's what I did.' The truth of this account was made manifest, by the boy not only retaining his hat on his head, but its being perfectly dry; and what adds to the singularity of this event, the boy never quitted his grasp of the knife that he was eating his bread and cheese with."

Mr. Knight Spencer found, that he was buoyant on the surface of the sea, even when he held stones, weighing six pounds avoirdupois, in his hands. In the water, however, the stones lost two pounds five ounces in weight, so that he was really freighted with no more than three pounds eleven ounces. He himself weighed one hundred and thirty pounds.[1] Dr. Franklin,[2] whilst he considered the detached members of the body, and particularly the head, as of greater weight than their bulk of water, acknowledged the body in the aggregate to be of less specific gravity, by reason of the hollowness of the trunk. He thought, that a body immersed in water would sink up to the eyes, but that if the head were inclined back, so as to be supported by the water, the mouth and nostrils would remain above,—the body rising one inch at every inspiration, and sinking one inch at every expiration; and also that clothes give little additional weight in the water, although, in stepping out of it, the case is quite otherwise. He concluded, therefore, that if a person could avoid struggling and plunging, he might remain in the posture described with safety. That the body

[1] Fleming's Philos. of Zoology, vol. i., Edinb., 1822.

[2] Works, iii. 374, Philad., 1808; and Sparks's edit., vi. 289, Boston, 1838.

is to a certain degree buoyant, he refers to the experience of every one who has ever attempted to reach the bottom of deep water,—the effort required sufficiently proving that something resists our sinking.

The truth would appear to be, that there is only a slight difference between the specific gravity of the human body and that of water; the former being something greater, otherwise there would be no reason why the dead body should sink to the bottom, as it is known to do. It would seem, however, where the deposition of fat is excessive, the body may be of much less specific gravity than water.[1] The old notion was, that, in the living state, the specific gravity of the body is decidedly less; but that, in death from drowning, a quantity of water always enters the lungs and stomach, and thus these cavities being no longer occupied with air, buoyancy is lost and the body sinks. Nothing is now better established than that no water gets into the stomach, except what is accidentally swallowed during the struggling; and that no water must be looked for in the lungs; a quantity of frothy mucus being all that is generally perceptible there. Yet, in courts of justice, the absence of water in these situations has been looked upon as evidence, where a body has been found in the water, that death had not occurred from drowning; and attention has consequently been directed to other causes, which might have produced it: the presumption in such cases being, that the person had been first killed, and then thrown into the water for the purpose of averting suspicion.

Another erroneous opinion, at one time prevalent, was, that if a person be thrown alive into water he will sink; if dead, he will swim; and, therefore, it is necessary that some weight should be attached to a body, when committed to the deep, to make it sink. All these fallacious notions are dwelt upon in a case, full of interest to all jurists, medical and others;—that of Spencer Cowper, Esq., a member of the English bar, and afterwards one of the judges of the Court of Common Pleas, who, with three other individuals, was tried at Hertford Assizes, in 1699, for the murder of Mrs. Sarah Stout.[2] The speeches of the counsel, with the evidence of many of the medical witnesses, sufficiently testify the low condition of medico-legal knowledge at that period.[3] Mr. Jones—the counsel for the prosecution—affirmed, that "when her (Mrs. Stout's) body came to be viewed, it was very much wondered at; for, in the first place, it is contrary to nature, that any persons, that drown themselves, should float upon the water." "We have sufficient evidence," he adds, "that it is a thing that never was: if persons go alive into the water, then they sink; if dead, then they swim." In confirmation of this strange opinion, two seamen were examined, one of whom deposed as follows:—"In the year '89 or '90, in Beechy fight, I saw several thrown overboard during the engagement, but one particularly I took notice of, that was my friend, and killed by my side. I saw him swim for a considerable distance from the ship, &c. Likewise in another engagement, where a man had both his legs shot off and died instantly, they threw over his legs; though they sunk, I saw

[1] See vol. i., p. 494, under Adipous Exhalation.

[2] Hargrave's State Trials, vol. v.; Beck's Medical Jurisprudence, 6th edit., ii. 205, Albany, 1838.

[3] Lives of the Lord Chancellors, by Lord Campbell, Amer. edit., iv. 240, Philad., 1848.

his body float; likewise I have seen several men, who have died natural deaths at sea; they have, when they have been dead, had a considerable weight of ballast made fast to them and so were thrown overboard; because we hold it for a general rule that all men swim if they be dead before they come into the water, and, on the contrary, I have seen men when they have been drowned, that they have sunk as soon as the breath is out of their bodies," &c. The weights are, however, attached to the dead, when they are thrown into the sea, not for the purpose of facilitating their descent, but to prevent them from rising, when putrefaction renders them buoyant, by the disengagement of air in the splanchnic cavities. On the same trial, Drs. Coatsworth, Burnet, Nailor, and Woodhouse deposed, that when a person is drowned, water will be taken into the stomach and lungs; and as none was found in the case of Mrs. Stout, they were of opinion, that she came to her death by other means.

From all that has been said, it would appear, that the great requisite for safety to the inexperienced who may fall accidentally into water is a firm and sufficient conviction of the fact, that the living body naturally floats, or that it can be easily made to do so. This conviction being acquired, no more than a common share of presence of mind would seem to be necessary to insure, that the portion of the body, which is the great outlet of the respiratory organs, shall be above the surface.

The movements, adapted to the progression of the body, are to be acquired in the same manner as a child learns to walk; proficiency in this, as in every thing else, being the result of practice.

Swimming nearly resembles leaping, except that the effort in it does not take place from a fixed surface. Both the upper and lower extremities participate in it. Whilst the former are brought to a point anterior to the head, and form a kind of cut-water, the lower extremities are drawn up, and suddenly extended, as in leaping. The water, of course, yields to their impulse; but not as rapidly as it is struck, and hence the body is projected forwards. The upper limbs are now separated, and carried circularly and forcibly round to the sides of the body, by which the impulse is maintained; the legs are in the meantime drawn up; and, by a succession of these movements, progression is effected—the hands and feet being turned outwards to present as large a resisting surface as possible. The chest is, at the same time, kept dilated, to augment the bulk of the body, and, of course, to render it specifically lighter, and the head is raised above the surface to admit of respiration. This action is analogous to that of the propulsion of a boat by oars. The body resembles the boat; and the upper and lower extremities are the oars or sculls.

The practised swimmer can execute almost as many movements in the water as he can on land.

e. *Flying.*

If the human body sinks in the water, how little can it be susceptible of suspension in the air by its own unassisted muscular powers! This is a mode of progression which is denied to man; and accordingly, most of the attempts at flying, since the mythical exploits of Dædalus and

Icarus, have been confined to enabling the body to move from one place to another by means of ropes and appropriate adjuncts. Years ago, a native of this country exhibited a curious variety of progression at Dover, England. He was called the "*flying phenomenon;*" and his plan, so far as we can recollect, was to have a rope extending from the heights to the beach beneath, along which he descended by means of rings attached to different parts of his person, which had the rope passing through them.

The sources of difficulty, in flying, are;—the great weight of the body, and the insufficient force which the muscles are capable of exerting. It is by no means impossible, however, that by some contrivance, of which the lightest gases might form a part, and by an imponderous apparatus, which would enlarge the surface of the upper extremities, progression, in this manner, might be effected;—but to a limited and unmanageable extent only.

f. *Other Varieties of Muscular Action.*

Connected with this subject we may refer briefly to some varieties of muscular action, the nature of which will be easily intelligible.

In *bearing a load*, we have simply a variety of walking in the erect attitude, with this addition, that the extensor muscles of the head, neck, or back,—according to the part on which the burden may be placed,—have to contract forcibly to support it. The position of the individual has, also, to be so regulated, that the centre of gravity shall always be over the base of sustentation. Hence, if the load be on a man's back, he leans forward; if borne before him, he leans backward; and this is the cause of the portly and consequential appearance of the corpulent. If the load be on his head he stands as upright as possible, for a like reason.

In *propelling a body* forwards, either by the hands or shoulders, the feet are firmly fixed on the ground; the limbs are in a state of semi-flexion, and the centre of gravity is directed forward, so as to aid the force that has to be developed by the muscles. The limbs are then suddenly extended; the body is thrown forward, and the whole power exerted on the obstacle which has to be moved.

On the other hand, when we *drag a weight* after us, or attempt to *dislodge a stake* from the earth, the feet are equally fixed firmly on the ground, but the body is in a state of extension, and is directed as far as practicable backwards, in order that the tendency to fall, owing to the centre of gravity overhanging the base of sustentation, may aid the force that has to be developed by the flexor muscles of the arms, which are then powerfully contracted, and the whole force is exerted upon the object. As, in both these cases, there is danger of falling should the body yield suddenly, the feet are so placed as to obviate this, as far as possible, by being separated in the direction in which the force is exerted.

Squeezing consists in laying hold of the object, either between the arms and body, or by the fingers; and then forcibly contracting the flexor muscles. In all these, and other varieties of strong muscular contraction, the respiration is interrupted, in order that the thorax may be rendered fixed, and serve as an immovable point of origin for

the muscles of the head, shoulders, and arms. This is effected by taking in a full inspiration; strongly contracting the respiratory muscles, and, at the same time, closing the glottis to prevent the exit of the air.

Lastly: as organs of *prehension*, the upper extremities are of admirable organization, possessing great mobility, and at the same time solidity. The joint at the shoulder allows of extensive motion; and the bones, to which the arm is attached at this joint—scapula and clavicle—are themselves movable. The forearm is likewise susceptible of various movements on the arm, of which those of pronation and supination are not the least important; whilst the hand possesses every requisite for an organ of prehension. It is composed of numerous bones, and is capable of being applied to the most irregular surfaces. The great superiority of the human hand arises from the size and strength of the thumb, which can be brought into a state of opposition to the fingers; and is, therefore, of the highest use in enabling us to seize hold of, and grasp spherical bodies; to take up any object; to lay firm hold of whatever we seize, and to execute the various useful, and ornamental processes of the arts. These processes require the most accurate, quick, and combined movements of the muscles. How quick, for example, is the motion of the hand in writing, and in executing the most rapid movements on the piano-forte! How accurate the muscular contraction, which stops the precise part of the violin-string to bring out the note or semi-tone in *allegro* movements; and what a multitude of combinations must be invoked in all these cases!

As an organ of touch, the advantages of the upper extremity have already been depicted; and much of what was then said applies to it as an organ of prehension. "In this double respect," observes M. Adelon,[1] "man is the best provided of animals. How much, in fact, does he stand in need of an ingenious instrument of prehension! As we have several times remarked, he has, in his organization, neither the offensive nor defensive arms, that are bestowed on other animals. Naked from birth, and exposed to the inclemencies of the atmosphere, without means of attack or defence against animals, he must incessantly labour to procure what he requires. It was not, consequently, enough that he should possess an intellect, capable of making him acquainted with, and of appropriating to himself, the universe. He must have an instrument adapted for the execution of all that his intellect conceives. Such instrument is his upper extremity. In short, whilst other animals find every thing in nature—necessary for their different wants—more or less prepared; man, alone, is obliged to labour to procure what he requires. He must make himself clothes, construct his habitations, and prepare his food. He is the *labouring* and *producing* animal *par excellence;* and hence needs not only an intellect to conceive but an instrument to execute."

5. FUNCTION OF EXPRESSION OR LANGUAGE.

Under this head will be included those varieties of muscular contraction, by which man and animals exhibit the feelings that impress

[1] Physiologie de l'Homme, ii. 201, 2de édit., Paris, 1839.

them, and communicate the knowledge of such feelings to each other. It comprises two different sets of actions;—those addressed to the ear—or phenomena of *voice;* and those appreciated by the senses of sight and touch—or *gestures.* Of these we shall treat consecutively.

a. *Of the Voice.*

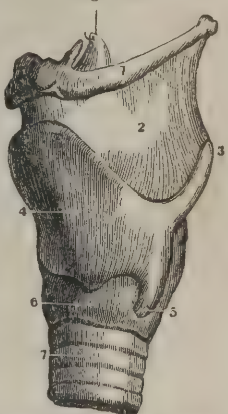
By *voice* or *phonation*—a term proposed by Chaussier—is meant the sound produced in the larynx, whilst the air is passing through it, either to enter, or issue from, the trachea.

1. ANATOMY OF THE VOCAL APPARATUS.

The apparatus, concerned in the production of voice, is composed, in man, of the muscles concerned in respiration; the larynx; the mouth and nasal fossæ. The first are merely agents for propelling the air through the instrument of voice. They have already fallen under consideration under Respiration; whilst the anatomy of the mouth and nasal fossæ has been described in other places. The larynx, and its primary dependencies, which are immediately concerned in the production of voice, will alone engage us at present.

The larynx is situate at the anterior part of the neck, and forms the projection so perceptible in that of the adult male, called *pomum Adami.* An attentive examination of the various parts which compose it, so far as they concern its physiological relations, will be necessary. This will exhibit the imperfect knowledge of several writers on the voice, and the false and insufficient views that have been entertained on the subject.

Fig. 381.



Lateral View of the Larynx.

1. Os hyoides. 2. Thyro-hyoid ligament. 3. Cornu majus of thyroid cartilage. 4. Its angle and side. 5. Cornu minus. 6. Lateral portion of cricoid cartilage. 7. Rings of trachea.

If we look along the larynx from the trachea of which it is a continuation, we find that the tube becomes gradually narrower from side to side; and, at length, presents an oblong cleft, called *glottis*, the sides of which are the essential organ of voice.

The larynx is composed of four cartilages—the *cricoid*, *thyroid*, and two *arytenoid.* The cricoid is the lowest of these, and is the inferior part of the organ;—that by which it joins the trachea. It is shaped like a ring, whence its name, but is much deeper behind than before. The thyroid is situate above the cricoid, with which it is articulated in a movable manner by means of its inferior cornua. In this way, the lower front margin of the thyroid, which is commonly separated by a short space from the upper margin of the cricoid, may be made to approach to or recede from it; as may be ascertained by placing the finger against the small depression felt externally, and observing its change of size when various tones are sounded. It will be observed, that the higher the tone the more the cartilages approximate, and that they separate in proportion to the depth of the tone. A ligament unites these cartilages—the *crico-thyroid*—which can be traced, although in a very thinned

condition, over the whole of the periphery of the ventricle of the larynx, even as far the pedicle of the epiglottis. This membrane is composed of the yellow elastic tissue—*tissu jaune*—and, according to Dr. Leidy,[1] it presents, under the microscope, a good example of that substance, which enabled him to detect its presence in the ventricles of the larynx.

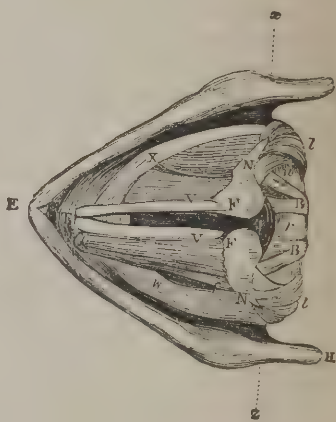
The thyroid is the large cartilage that occupies the anterior, prominent, and lateral part of the larynx. The arytenoid cartilages are two in number. They are much smaller than the others, and are articulated with the posterior part of the cricoid in a movable manner. Around this articulation is a synovial capsule. Before it is the *thyro-arytenoid* ligament; and, behind, a strong, ligamentous fascia, called, by M. Magendie,[2] from its attachments—*crico-arytenoid.* Three fibro-cartilages, likewise, enter into the constitution of the larynx. These

Fig. 382.

View of the interior of the left half of the Larynx, to show the Ventricle and Laryngeal Pouch.

a. Left arytenoid cartilage. *c*, *c*. Sections of the cricoid cartilage. *t*. Thyroid cartilage. *e*. Epiglottis. *v*. Left ventricle of the larynx. *r*. Left inferior or true vocal cord. *s*. Laryngeal pouch. *b*. Aryteno-epiglottidean muscle, or compressor sacculi laryngis. *f*. Inside of trachea, which has been added to this figure.

Fig. 383.



Larynx from above.

G E H. Thyroid cartilage, embracing the ring of the cricoid *r u x w*, and turning upon the axis *x z*. N F, N F. The arytenoid cartilages, connected by the arytenoideus transversus. T V, T V. The vocal ligaments. N X. The right crico-arytenoideus lateralis (the left being removed). V *k f*. The right thyro-arytenoideus (the left being removed). N *l*, N *l*. The crico-arytenoidei postici. B B. The crico-arytenoid ligaments.

are,—the *epiglottis;* and two small bodies, that tip the arytenoid cartilages,—and are met with only in man—*capitula Santorini*, *supra-arytenoid cartilages* or *capitula cartilaginum arytenoïdarum.*

[1] Amer. Journ. of the Medical Sciences, July, 1846, p. 142.
[2] Précis Élémentaire, i. 235.

On examining the interior of the larynx, two clefts are seen—one above the other; the uppermost being usually oblong-shaped; ten or eleven lines long, and two or three broad; having the shape of a triangle, the apex forwards. It is circumscribed, anteriorly, by the thyroid cartilage and epiglottis; posteriorly, by the arytenoid cartilages; and, laterally, by two folds of mucous membrane, which pass from the epiglottis to each arytenoid cartilage, and are called *superior ligaments of the glottis* and *superior vocal cords.* A few lines below this is a second cleft, also oblong from before to behind and of a triangular shape, the base of which is behind. It is bounded anteriorly by the thyroid cartilage; posteriorly, by a muscle extending from one arytenoid cartilage to the other—the *arytenoideus;* and, laterally, by two folds, formed of the thyro-arytenoid ligament, passing from the anterior part of the arytenoid cartilage to the posterior part of the thyroid, and of a muscle of the same name. These folds are called *inferior ligaments* or *lips of the glottis* or *inferior vocal cords.* They are represented by T V, in Fig. 383, and B B, Fig. 387. Between these two clefts are the *sinuses* or *ventricles of the larynx*, *v*, Fig. 382, and V V, Fig. 387. The inferior, exterior, and superior sides of these are

Fig. 384.

Larynx from above.

c c, Pyramidal or arytenoid cartilages; *a*, cricoid or basement cartilages; *e e*, the tongues or proper vocal cords, called also vocal ligaments, also arytenothyroid ligaments and inferior vocal ligaments; *f f*, the ventricles of the larynx; *d*, the epiglottis.

Fig. 385.

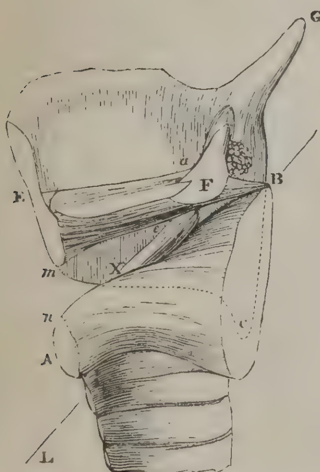
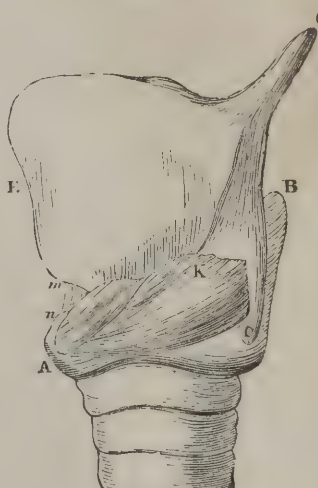


Fig. 386.



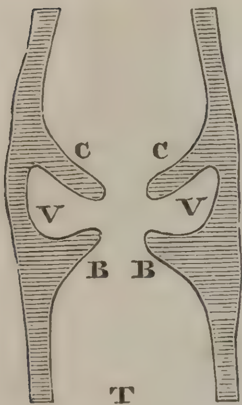
External and Sectional views of the Larynx.

A *n* B. The cricoid cartilage. E C G. The thyroid cartilage. G. Its upper horn. C. Its lower horn, where it is articulated with the cricoid. F. The arytenoid cartilage. E F. The vocal ligament. A K. crico-thyroideus muscle. F *e m*. Thyro-arytenoideus muscle. X *e*. crico-arytenoideus lateralis. *s*. Transverse section of arytenoideus transversus. *m n*. Space between thyroid and cricoid. B L. Projection of axis of articulation of arytenoid with thyroid.

formed by the thyro-arytenoid muscles. By means of these ligaments—superior and inferior—the lips of the superior and inferior aperture are perfectly free, and unencumbered in their action.[1]

Anatomical descriptions will be found to give different significations to the word *glottis*. Some have applied it to the upper cleft; others to the lower; some to the ventricles of the larynx; and others to the whole space comprised between the inferior ligaments and top of the larynx. It is now, generally perhaps, restricted to the part of the larynx engaged in the production of voice, or usually considered to be so engaged,—that is, the space between the inferior ligaments plus the ligaments themselves;—and in this signification it will be employed here.

Fig. 387.



Scheme of the Larynx.

The mucous membrane, which lines the larynx, is continuous above with that of the mouth; below, with that of the trachea. It contains several mucous follicles, some of which are agglomerated near the superior ligaments of the glottis and the environs of the ventricles of the larynx, seeming to constitute distinct organs, which have been called *arytenoid glands*. A similar group exists between the epiglottis behind, and the os hyoides and thyroid cartilage before, which has been termed the *epiglottic gland*. The uses of this body are not clear. M. Magendie[2] conceives, that it favours the frequent slidings of the thyroid cartilage over the posterior surface of the os hyoides; keeps the epiglottis separated above from this bone; and, at the same time, furnishes it a very elastic support, which may aid it in the functions it has to execute, connected with voice and deglutition.

The larynx is capable of being moved as a whole, as well as in its component cartilages. It may be raised, depressed, or carried forwards or backwards. The movements, however, which are most concerned in the production of voice, are those effected by the action of the *intrinsic* muscles, as they have been termed. These are, 1st. The *crico-thyroid*, a thin, quadrilateral muscle, which arises from the anterior surface of the cricoid cartilage, and is inserted into the lower and inner border of the thyroid. M. Magendie[3] affirms, that its use is not, as generally imagined, to depress the thyroid on the cricoid, but to elevate the cricoid, approximate it to the thyroid, and even make it pass slightly under its inferior margin. The effects of its contraction must be to render the vocal ligaments tense. 2dly. The *crico-arytenoidei postici*, and *crico-arytenoidei laterales;* the former of which pass from the posterior surface of the cricoid to the outer angle of the base of the arytenoid; and the latter from the upper border of the side of the cricoid to the outer angle of the base of the arytenoid. The use

[1] Hilton, Guy's Hospital Reports, No. v., October, 1837, p. 519, and Leidy, American Journal of the Medical Sciences, p. 142, July, 1846.

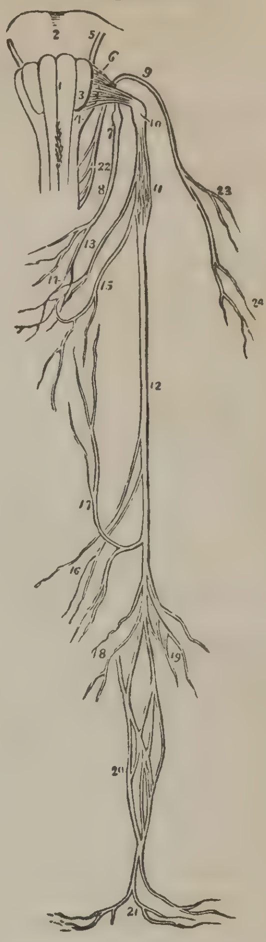
[2] Précis, &c., i. 237.

[3] Ibid., i. 236.

of the crico-arytenoidei postici is to carry the arytenoid cartilages backwards, separating them at the same time from each other, and thus opening the glottis; the action of the crico-arytenoidei laterales is like that of the arytenoidei to bring together the inner edges of the arytenoid cartilages, and close the glottis. 3dly. The *arytenoid muscle*—of which there is only one. It extends across from one arytenoid cartilage to the other; and, by its contraction, brings them towards each other. 4thly. The *thyro-arytenoid muscle*, which, according to M. Magendie,[1] is the most important to be known of all the muscles of the larynx, as its vibrations produce the vocal sound. It forms the lips of the glottis, and Magendie describes it as constituting, also, "the inferior, superior, and lateral parietes of the ventricles of the larynx." Generally, it is considered to arise from the posterior surface of the thyroid cartilage, and the ligament connecting it with the cricoid, and to be inserted into the anterior edge of the base of the arytenoid. By drawing the point of the thyroid back, it must relax the vocal ligaments. Lastly.—The muscles of the epiglottis—the *thyro-epiglottideus*, *aryteno-epiglottideus superior*, *aryteno-epiglottideus inferior* (Hilton's muscle),[2] and some fibres that may be looked upon as *vestiges* of the *glotto-epiglotticus*, which exists in many animals. These muscles,—the position of which is indicated by the name,—modify by their contraction the situation of the epiglottis.

The principal governors of the pitch of the voice, which is almost wholly regulated by the degree of tension of the vocal ligaments, are the crico-thyroid and thyro-arytenoid.

Fig. 388.



Origin and Distribution of the Pneumogastric and Spinal Accessory Nerves.

1, 3, 4. Medulla oblongata. 1. Corpus pyramidale of one side. 3. Corpus olivare. 4. Corpus restiforme. 2. Pons Varolii. 5. Facial nerve. 6. Origin of glosso-pharyngeal nerve. 7. Ganglion of Andersch. 8. Trunk of the nerve. 9. Spinal accessory nerve. 10. Ganglion of pneumogastric nerve. 11. Its plexiform ganglion. 12. Its trunk. 13. Its pharyngeal branch forming the pharyngeal plexus (14), assisted by a branch from the glosso-pharyngeal (8), and one from the superior laryngeal nerve (15). 16. Cardiac branches. 17. Recurrent laryngeal branch. 18. Anterior pulmonary branches. 19. Posterior pulmonary branches. 20. Œsophageal plexus. 21. Gastric branches. 22. Origin of spinal accessory nerve. 23. Its branches distributed to sterno-mastoid muscle. 24. Its branches to the trapezius muscle.

[1] Précis; &c., i. 236, and his Mémoire sur l'Épiglotte.
[2] Wilson's Anatomist's Vade Mecum, Amer. edit., p. 483, Philad., 1843.

The respective action of the different muscles has been given in tabular form.[1]

Govern the Pitch of the Notes.

	Muscles	Action
Antagonists.	Crico-thyroidei Sterno-thyroidei	Depress the front of the thyroid cartilage on the cricoid and *stretch* the vocal ligaments; assisted by the arytenoideus and crico-arytenoidei postici.
	Thyro-arytenoidei Thyro-hyoidei	Elevate the front of the thyroid, and draw it towards the arytenoid, *relaxing* the vocal ligaments.

Govern the Aperture of the Glottis.

	Muscles	Action
Antagonists.	Crico-arytenoidei postici . .	*Open* the Glottis.
	Crico-arytenoidei laterales . . Arytenoideus	Press together the inner edges of the arytenoid cartilage, and *close* the glottis.

The intrinsic muscles of the larynx receive their nervous influence from the eighth pair and the spinal accessory (Fig. 388). Shortly after the former has issued from the cranium it gives off a branch, called *superior laryngeal*, which is distributed to the arytenoid and crico-thyroid muscles; and, after its entrance into the thorax, it furnishes a second, which ascends towards the larynx, and is, on that account, called *recurrent* or *inferior laryngeal.* It is distributed to the crico-arytenoidei postici, crico-arytenoidei laterales, and thyro-arytenoid muscles. No ramification of this nerve, according to M. Magendie, goes to the arytenoid, or crico-thyroid muscles. In these views, he is supported by M. J. Cloquet[2] and by many others. Other distinguished anatomists, however, maintain that the arytenoideus muscle receives a branch from each of the inferior laryngeals. Dr. Reid asserts, that he has repeatedly satisfied himself of the existence of this arytenoid branch of the inferior laryngeal, and the dissection is one, he says, which can leave no kind of doubt on the matter.[3]

As the trunk of the spinal accessory nerve passes through the foramen lacerum it divides into two branches; the internal, after giving off filaments which assist in forming the pharyngeal branch of the pneumogastric, becomes confounded with the trunk of that nerve; and is distributed along with it to the muscles of the larynx, and especially to the crico-thyroid.

In each animal species, the glottis has a construction corresponding to the kind of voice; and, when it is examined in the living animal—the dog for example—it enlarges and contracts alternately,—the arytenoid cartilages separating when the air enters the lungs, and approximating during expiration.

To the trachea the larynx is attached by a fibrous membrane, which unites the cricoid with the first ring of the trachea; and, above, it is connected with the os hyoides by a similar membrane—the thyro-hyoid, No. 2, Fig. 381,—as well as by the thyro-hyoid muscle.[4]

[1] Carpenter's Human Physiology, 4th Amer. edit., § 604, Philad., 1850.

[2] Traité d'Anatomie Descriptive, ii. 622, Paris, 1816.

[3] Art. Par Vagum, by Dr. J. Reid, in Todd's Cyclopædia of Anat. and Physiol., Parts xxvii. and xxviii. p. 893, London, 1846–7. For an excellent description of the anatomy of the vocal apparatus, see J. Bishop, art. Larynx, Cyclop. of Anat. and Physiol., Lond., Sept., 1840.

[4] Willis, in Cambridge Philosoph. Transact. for 1832, iv. 323.

2. PHYSIOLOGY OF VOICE.

The production of voice requires, that air shall be sent from the lungs, which, in passing through the glottis, throws certain parts into vibration, and afterwards makes its exit by the *vocal* tube,—that is, by the mouth and nasal fossæ. Simple expiration does not, however, produce it, otherwise we should have the vocal sound accompanying each contraction of the chest. Volition is necessary to excite the requisite action of the muscles of the larynx, as well as those of respiration; and by it the tone and intensity of voice are variously modified.

That voice is produced in the larynx, we have both direct and indirect testimony. An aperture made in the trachea, beneath the larynx, deprives both man and animals of it. This occurs also, if the aperture be made in the larynx beneath the inferior ligaments; but if above the glottis, so as to implicate the epiglottis and its muscles, the superior ligaments of the glottis, and even the upper portions of the arytenoid cartilages, voice continues. MM. Magendie[1] and J. Cloquet refer to the cases of two men, who had fistulæ in the trachea; and who were unable to speak unless the openings were accurately stopped by mechanical means. If, again, we take the trachea and larynx of an animal or man, and blow air forcibly into the tracheal extremity towards the larynx, no sound is produced, except what results from the friction of the air against the sides. But if we approximate the arytenoid cartilages, so that they touch at their inner surfaces, a sound is elicited, bearing some resemblance to the voice of the animal to which the larynx belongs;[2]—the sound being acute or grave according as the cartilages are pressed against each other with more or less force; and varying in intensity, according to the degree of force with which the air is sent through the tube. In this experiment, the inferior ligaments are seen to vibrate.

Paralysis of the intrinsic muscles of the larynx likewise produces dumbness; and this can be effected artificially. Much discussion at one time prevailed regarding the effect of tying or cutting the nerves distributed to these muscles. The experiments of Haighton[3] induced him to think, that the recurrent branches of the par vagum supply parts, which are essentially necessary to the formation of the voice; whilst the laryngeal seemed to him to affect only its modulation or tone. Subsequent experiments have sufficiently shown, that if both the recurrent nerves and the superior laryngeal are divided, complete aphonia results. M. Magendie[4] found, indeed, that when both recurrents,—which, he says, are distributed to the thyro-arytenoid muscles,—are cut, the voice is usually lost; whilst if one only be divided, the voice is but half destroyed. He noticed, however, that several animals, in which the recurrents had been cut, were still capable of eliciting acute sounds, when labouring under violent pain,—sounds, which were analogous to those that could be produced mechanically on the larynx of the dead animal, by blowing into the trachea and approximating the arytenoid cartilages; and this he attempts to explain by

[1] Précis, &c., i, 241, and his Journal de Physiologie, ix. 119.
[2] Biot, Traité Elémentaire de Physique, i. 462.
[3] Memoirs of the Medical Society of London, iii. 435.
[4] Précis, &c., i. 243.

the distribution of the nerves to the larynx. The recurrents being divided, the thyro-arytenoid muscles are no longer capable of contracting, and aphonia results; but the arytenoid muscle, which receives its nerves from the superior laryngeal, still contracts; and, during a strong expiration, brings the arytenoid cartilages together, so that the chink or cleft of the glottis is sufficiently narrow for the air to cause vibration in the thyro-arytenoid muscles, although they may not be in a state of contraction. From these, and other experiments, Bellingeri[1] infers, that the superior laryngeal nerve is the antagonist of the inferior laryngeal or recurrent,—the former producing constriction; the latter dilatation of the glottis. They, however, who affirm, that the distribution of the laryngeal nerves is not the same as that described by M. Magendie, assign different functions to the particular nerves. Thus, Mr. Hilton[2] infers from his observations—*first*, that the superior laryngeal is a nerve of sensation; because, independently of the crico-thyroideal nerve, it is distributed exclusively to the mucous membrane, areolar tissue, and glands; and *secondly*, that the inferior or recurrent must be the proper motive nerve to the larynx, as it alone supplies all the muscles, which act immediately upon the column of air passing to and from the lungs. Dr. Reid[3] too, concludes from his various experiments;—*first*, that the superior laryngeal furnishes one muscle only with motor filaments,—the crico-thyroid. *Secondly*, that the superior laryngeal furnishes all, or nearly all, the sensitive filaments of the larynx, and some of those distributed upon the mucous surface of the pharynx. *Thirdly*, that the inferior laryngeal or recurrent furnishes the sensitive filaments to the upper part of the trachea, a few to the mucous surface of the pharynx, and still fewer to the mucous surface of the larynx; and *fourthly*, that when any irritant is applied to the mucous membrane of the larynx in a healthy state, this does not excite the contraction of the muscles, which move the arytenoid cartilages, by acting directly upon them through the mucous membrane, but the contraction takes place by a reflex action, in the performance of which the superior laryngeal is the sensitive, and the inferior laryngeal the motor nerve.

Until recently, the action of the spinal accessory nerve, as regards the movements of the larynx in the production of voice, was generally confounded with that of the superior laryngeal nerves, and it has been a question, often agitated, whether all or a great part of the motor filaments, that appear to belong to the pneumogastric nerves may not be given to them from the accessory nerves.[4] Its function has, of late years, been more closely investigated, especially by M. Bernard,[5] who assigns to its internal branch an important influence in vocalization in adapting the action of the muscles of the larynx and

[1] Ragionamenti, Sperienze, &c., comprovanti l'Antagonismo Nervoso, &c., Torino, 1833; noticed in Edinb. Med. and Surg. Journal, p. 172, Jan., 1835.

[2] Op. cit., p. 518, and Mr. Cock, on the Crico-Thyroideal Nerve, a branch of the superior laryngeal, ibid., p. 313.

[3] Op. cit., p. 145.

[4] Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 362, Philad., 1853.

[5] Recherches Expérimentales sur les Fonctions du Nerf Spinal, in Archives Générales de Médecine, 1844, and Recueil des Savants Étrangers, Tom. xi., 1851; see, also, Béraud, Manuel de Physiologie, p. 779, Paris, 1853.

the thorax to the production of voice. When the nerves were divided in his experiments, as well as in those of Bischoff, Longet,[1] and others, aphonia was the result as when the recurrents were cut.

When one spinal accessory nerve is destroyed, the voice becomes raucous; when both are, aphonia is complete. The respiration, however, continues as in the normal condition even in very young animals. Hence M. Bernard ascribes a "vocal" influence to it; and Longet considers that it alone merits the name of *vocal nerve*;[2]—the movements of the larynx in phonation being under its influence; whilst those concerned in ordinary respiration are under the pneumogastric; and it has been inferred, that all the intrinsic movements of the larynx which have been referred to the superior and inferior laryngeal nerves are owing to the admixture of filaments of the spinal accessory.[3]

It is obvious, however, that we have yet much to learn before we can pronounce with certainty on the precise function of the nerves of the larynx.

Every part of the larynx, with the exception of the inferior ligaments, may be destroyed, and the voice continue. Bichat split the upper edge of the superior ligaments of the glottis, without its being destroyed; and the excision of the tops of the arytenoid cartilages had no more effect. Magendie divided with impunity the epiglottis and its muscles: voice was accomplished, until he cut the middle of the arytenoid cartilages, or split the thyroid cartilages longitudinally, when he, of course, destroyed the glottis. Lastly, when the larynx is exposed in a living animal, so that the different parts can be seen at the time when voice is accomplished,—the superior ligaments, according to Bichat and Magendie, who have performed the experiment, are manifestly unconcerned in the function, whilst the inferior vibrate distinctly. These ligaments must, therefore, be regarded as the essential organs of voice.[4]

The interesting, but difficult problem now presents itself; to determine the precise mechanism of the vibration of those ligaments; and what kind of instrument the vocal organ resembles. The latter question, on which, it might be conceived, so much physical evidence must exist, has been a topic of dissension, and is not settled at this day. Aristotle,[5] Galen,[6] and the older writers in general, looked upon the larynx as a wind instrument of the flute[7] kind, in which the interior column of air is the sonorous body; the trachea, the body of the flute; and the glottis the beak. The air, they conceived, when forced from the lungs, in passing through the glottis, is broken by the inferior ligaments of the larynx; vibrations are, consequently, produced, and these give rise to the sound. Fabricius, of Acquapendente,[8] was one of the first to object to this view of the subject. He properly re-

[1] Traité de Physiologie, ii. 370, Paris, 1850. See, also, Ibid., Tom. i. Fascic. 3, p. 151, Paris, 1852.

[2] Ibid., p. 151 (note).

[3] Béclard, Traité Élémentaire de Physiologie Humaine, pp. 573, 791, Paris, 1855.

[4] Précis, &c., i. 242.

[5] Opera, lib. ii. Problemat., § xi.

[6] Opera: de Larynge, lib. vii.

[7] The flute, here alluded to, is the common *flute* or *flute à bec*, in which the *embouchure* is at one extremity.

[8] De Locutione, &c., in Oper., Lugd. Bat., 1737.

marked, that the trachea cannot be regarded as the body of the flute, but as a *porte-vent* to convey air to the glottis. He was of opinion, that the glottis corresponds to the beak of the flute, and that the vocal tube, or the part above it, resembles the body of the instrument. Similar opinions, with more or less modification, have been adopted by Blumenbach,[1] Sömmering,[2] Savart,[3] &c. About the commencement of the last century, Dodart[4] laid before the *Académie des Sciences* of Paris three memoirs on the theory of voice, in which he considered the larynx to be a wind instrument of the horn, not of the flute, kind; the inferior ligaments of the glottis being to the larynx what the lips are to the performer on the horn. In 1741, Ferrein,[5] in a communication also made to the *Académie des Sciences*, maintained, that the larynx is a stringed instrument;—the sound resulting from the oscillation, caused in what he called the *chordæ vocales* or inferior ligaments of the larynx, by the air in expiration; and a modification of this view was professed by Dr. Young.[6]

At the present day, the majority of physiologists and natural philosophers regard the larynx as a wind instrument, of the reed kind—as the clarionet, hautboy, &c, and they differ chiefly in explaining the various modifications of the tone and quality of voice; for almost all are agreed, that it is produced by the vibrations of the inferior ligaments of the glottis.[7] MM. Piorry and Jadelot, however, consider the glottis an instrument *sui generis*, eminently vital, which, of itself, executes the movements necessary for the production of vocal sounds. All we know of the physiology of the production of voice is,—that the expired air is sent into the larynx by the muscles of expiration,—that the intrinsic muscles of the larynx give to the inferior ligaments sufficient tension to divide the air, and that the air receives the vibrations, whence sound results. The process is very complex. Before a single word can be uttered, a series of actions must be executed: these, as stated by Sir C. Bell,[8] consist in compression of the chest; adjustment of the glottis; elevation and depression of the larynx, and contraction of the pharynx,—actions which will be readily understood after what has been already said on the mechanism of phonation.

a. Intensity or Strength of Voice.

The strength of a sound depends upon the extent of the vibrations of the body producing it. In the case of voice, it is dependent, in part, on the force with which the air is sent from the lungs, and in part on the size of the larynx. A strong, active person, with a capacious chest and prominent pomum Adami, that is, with a large larynx,—is of an organization the most favourable for a strong voice. But if the same individual, thus favourably organized, be reduced in strength, his

[1] Institutiones Physiologicæ, § 154, Gotting., 1798.
[2] Icones Organorum Gustûs et Vocis, Francof., 1808; and Corp. Human. Fabric., vi. 93.
[3] Journal de Physiologie, v. 367.
[4] Mémoir. de l'Acad. Royale des Sciences, 1700, p. 244, and 1707, p. 409.
[5] Ibid. pour 1741, p. 409, and Haller, Elem. Phys., ix. 3.
[6] Lectures on Natural Philosoph., i. 400, and Philos. Trans., for 1800, p. 141.
[7] Willis, in Cambridge Philosophical Transactions, vol. iv.
[8] Philos. Transact. for 1832, p. 299; and Nervous System, 3d edit., Lond., 1837.

voice is enfeebled; because, although the formation of the larynx may be favourable, he is incapable of sending the air through it with sufficient force to excite extensive vibrations of the vocal ligaments.

The voice of the male is much stronger than that of the female, of the eunuch, or child. This is greatly owing to his larynx being more developed. The change in the voice of the male at puberty is owing to the same cause,—the prominence of the pomum Adami, which is first observed at this age, indicating the elongation that has supervened in the lips of the glottis. As voice is commonly produced, both ligaments of the glottis participate; but if one should lose its power of vibrating, from any cause, as from paralysis of one-half the body, the voice loses, *cæteris paribus*, one-half its intensity. M. Magendie[1] affirms, that this is manifested by cutting one of the recurrents on the dog.

b. Tone of Voice.

Nothing can exceed the human organ of voice in variety of tones, and execution. Dr. Barclay[2] has endeavoured to calculate the different changes of which it is susceptible, proceeding on the principle, that where a number of movable parts constitutes an organ destined for some particular function, and this function is varied and modified by every change in the relative situation of the movable parts, the number of changes, producible in the organ, must at least equal the number of muscles employed, together with all the combinations of which they are capable. The muscles, proper to the five cartilages of the larynx, are at least seven pairs; and fourteen muscles, that can act separately or in pairs, in combination with the whole or with any two or more of the rest, are estimated to be capable of producing upwards of sixteen thousand different movements—not reckoning as changes the various degrees of force and velocity, with which they are brought into action. These muscles, too, are only the proper muscles of the larynx, or those restricted in their attachments to its five cartilages. They are but a few of the muscles of voice. In speaking, we use a great many more. Fifteen pairs of different muscles, attached to the cartilages or os hyoides, and acting as agents, antagonists, or directors, are constantly employed in keeping the cartilages steady, regulating their situation, and moving them as occasion requires,—upwards and downwards, backwards and forwards, and in every intermediate direction, according to the course of the fibres, or in the diagonal between different fibres. These muscles, independently of the former, are susceptible, it is calculated, of upwards of 1,073,841,800 different combinations; and, when they co-operate with the seven pairs of the larynx, of 17592186,044,415; exclusive of the changes that must arise from the different degrees of force, velocity, &c., with which they may be brought into action. But these muscles are not the whole that co-operate with the larynx in the production of voice. The diaphragm, abdominal muscles, intercostals, and all, that directly or indirectly act on the air, or on the parts to which the muscles of the glottis or os hyoides are attached, contribute their share. The numerical estimate would, consequently,

[1] Précis, &c., i. 245.

[2] A New Anatomical Nomenclature, &c., p. 70, Edinb., 1803.

require to be largely augmented. Mr. Bishop computes the number of muscles brought into action at the same time in the ordinary modulations of the voice to be one hundred.[1] Such calculations are, of course, only approximate; but they show the inconceivable variety of movement of which the vocal apparatus is directly or indirectly susceptible.

The tone of the voice has been a great stumbling-block to the physiologist and physicist. The mode, in which it is produced, and the parts more immediately concerned in the function, have been the object of various theories or hypotheses, regarding the voice.

Galen, under his theory, that the larynx is a wind instrument of the flute kind, of which the glottis is the beak and the trachea the body of the flute, ascribed the variety of tones to two causes—to variation in the length of the musical instrument, and in the embouchure. In the theory of Dodart, in which the human vocal instrument was likened to a horn, the inferior ligaments of the glottis being compared to the lips of the performer, no importance was attached to variation in the length of the instrument. He attributed variety of tones to simple alteration in the *embouchure* or mouth-piece,—in other words, to changes in the size of the glottis, by the action of its appropriate muscles; and the rising and falling of the larynx, he regarded as serving no other purpose than that of influencing mechanically the size of the aperture of the glottis; whilst Ferrein, who regarded the larynx as a stringed instrument, accounted for the variety of tones by different degrees of tension and length of the inferior ligaments of the glottis or *vocal cords*. In the production of acute tones, these cords were stretched and shortened. For grave tones, they were relaxed, and lengthened. He was of opinion, that the length of the vocal tube had no influence on the tone.

In later years, several new views have been propounded on this subject, and chiefly by MM. Cuvier, Dutrochet, Magendie, Biot, Savart, &c.,—men of the highest eminence in various departments of physical science.

M. Cuvier[2] attributes variety of tones, in the first place, to varied length of the vocal tube, and to differences in size of the aperture of the glottis; and, secondly, to the shape and condition of the external aperture of the tube,—that is, of the lips and nose. The larynx he regards as a wind instrument, in which the inferior ligaments act, not as cords, but like the reed of a clarionet, or the *lame* of an organ pipe. The lungs and their external muscular apparatus constitute the reservoir of air and bellows; the trachea conducts the air, and the glottis is the embouchure with its reed; the mouth, and the whole of the space comprised between the glottis and the opening of the lips, being the body of the instrument; whilst the openings of the nostrils are lateral holes, that permit the size of the instrument to be varied. The tones are changed by three causes of a similar character to those that modify them in musical instruments;—the length of the body of the instrument, and the variableness of the embouchure, and of the aperture at

[1] The London and Edinburgh Philosoph. Magazine, &c., for Sept., 1836, p. 209.

[2] Leçons d'Anatomie Comparée, tom. iv. 445.

the lower extremity of the instrument. The condition of the external aperture of the vocal tube has, doubtless, much to do with the character of the tone produced by the glottis; but its influence appears to be greatly limited to giving it rotundity, volume, or the contrary,—as will be seen hereafter; although analogy would seem to show, that the tone may be varied by more or less closure of the aperture. Many different notes can be produced in the first joint of a flute, if we modify the size of the opening at its extremity by passing the thumb more or less within it. It is doubtful, however, whether in man the altered size of the external aperture, or the elongation or decurtation of the tube exerts as much influence in the production of acute or grave sounds as Cuvier imagined.

M. Dutrochet[1] again, believes, that the vocal tube has no influence in the production of tones, and that the larynx is a simple vibrating instrument, uncomplicated with a tube, the vocal sound being caused by the vibrations into which the vocal cords are thrown by the impulse of the expired air. In his experiments, he saw the inferior ligaments vibrate; and he concludes, that the tone of the voice depends upon the number of vibrations of those ligaments in a given time, and that their number will necessarily vary greatly, as the dimensions of the ligaments,—that is, their length and thickness,—and their elasticity, are susceptible of incessant changes, by the contraction of the thyro-arytenoid muscle, of which they are essentially composed,—the ligament, covering the muscle, serving only "to prevent the collisions of the muscles at the time of vibration,"—as well as by that of the other intrinsic muscles of the larynx.

MM. Biot and Magendie[2] dissent from M. Dutrochet in some important points. Like him, they do not consider the human larynx to constitute a stringed instrument. They regard it as a variety of reed instrument, but consider the vocal tube to be of moment in the production of the voice. The objections they urge against the view of its resembling a stringed instrument are,—the kind of articulation between the arytenoid and cricoid cartilages, which admits of motion inwards and outwards only; and they ask how the vocal cords can retain the length requisite for the production of grave tones; and how they can elicit sounds of a volume so considerable as those of the human voice? They esteem it, consequently, a reed instrument of such nature as to be capable of affording very grave tones with a pipe of little length; and, with slight variation of its length, susceptible, not only of furnishing a certain series of sounds in harmonic progression, but all the imaginable sounds and shades of sounds in the compass of the musical scale which each voice embraces.

The theory of the reed instrument they apply to the vocal apparatus. The lips of the glottis are the reed, and the thyro-arytenoid muscles render them fit for vibrating. In his experiments, made on living dogs, M. Magendie saw, that when grave sounds were produced, the ligaments of the glottis vibrated in their whole extent, and the expired air issued through the whole of the glottis. In acute sounds, on the

[1] Mém. pour servir à l'Histoire Anat. et Physiol. des Végétaux et des Animaux, t. ii., Paris, 1837; and Adelon, Physiologie de l'Homme, edit. cit., ii. 239.

[2] Précis Élémentaire, &c., i. 248.

other hand, they vibrated only at their posterior part, and the air passed out through the part only that vibrated, the aperture being, consequently, diminished; and, when the sounds became very acute, they vibrated only at their arytenoid extremity, and scarcely any air issued; so that tones beyond a certain degree of acuteness cannot be produced in consequence of the complete closure of the glottis. The arytenoid muscle, whose chief use is to close the glottis at its posterior extremity, he conceives to be the principal agent in the production of acute sounds, and this idea was confirmed by the section of the two laryngeal nerves that give motion to this muscle, which was followed by loss of the power of producing almost all the acute tones; the voice, at the same time, acquiring a degree of habitual graveness, which it did not previously possess. The influence of contraction of the thyro-arytenoid muscles on the tones is exerted in increasing or diminishing the elasticity of the ligaments, and thus, in modifying the rapidity of the vibrations, so as to favour the production of acute or grave tones. He thinks, too, that the contraction of these muscles concurs greatly in closing, in part, the glottis, particularly its anterior half; although the course of its fibres, it would appear, ought rather to widen the aperture. The trachea or *porte-vent* has usually been thought to exert no influence on the nature of the sound produced. It has been conceived, however, by M. Grenié and others, that its elongation or decurtation may occasion some modification.

Thus much for the part that resembles the reed.—MM. Biot and Magendie include in their theory of the voice the action of the vocal tube likewise. This tube being, in man, capable of elongation and decurtation, of dilatation and contraction, and of assuming an infinite number of shapes, they think it well adapted, if placed in harmonic relation with the larynx, for fulfilling the functions of the body of a reed instrument,—and thus of favouring the production of the numerous tones of which the voice is capable; of augmenting the intensity of the vocal sound by assuming a conical shape with a wide external aperture; of giving rotundity and sweetness by the proper arrangement of its external outlet, or of entirely arresting it by the closure of the outlet. The larynx rises in the production of acute, and sinks in that of grave sounds. The vocal tube is, consequently, shortened in the former case; elongated in the latter. It experiences, also, a simultaneous change in its width. When the larynx descends,—in other words, when the vocal tube is elongated,—the thyroid cartilage is depressed, and separated from the os hyoides by the whole height of the thyro-hyoid membrane. By this separation, the epiglottic gland is carried forwards, and lodged in the concavity at the posterior surface of the os hyoides. The gland drags after it the epiglottis; and a considerable enlargement in width occurs at the inferior part of the vocal tube. The opposite effect results when the larynx rises. The use of the ventricles of the larynx, M. Magendie[1] considers to be, to isolate the inferior ligaments, so that they may vibrate freely in the air. Lastly; in this theory the epiglottis has a use assigned to it which is novel.

[1] Précis, &c., i. 252; see, also, Sir C. Bell, Philos. Transact. for 1832; and Nervous System, 3d edit., p. 484, Lond., 1837.

In certain experiments, instituted by M. Grenié[1] for the improvement of reed instruments—being desirous of increasing the intensity of sound without changing the reed in any respect—he found that, to succeed, he was compelled to augment gradually the strength of the current of air; but this augmentation, by rendering the sounds stronger, caused them to rise. To remedy this inconvenience, M. Grenié found nothing answer except placing obliquely in the tube, immediately below the reed, a supple, elastic tongue, nearly as the epiglottis is placed above the glottis. From this, M. Magendie[2] infers, that the epiglottis may assist in giving to man the faculty of increasing or inflating the vocal sound, without causing it to mount; but, as Mr. Bishop[3] properly remarks, neither the elevation nor depression of the epiglottis can affect or regulate the vibrations of the glottis.

Such are the main propositions of the theory of the voice by MM. Biot and Magendie. The larynx represents a reed with a double tongue: the tones of which are acute in proportion to the decurtation of the laminæ; and grave in proportion to their length. They admit, however, that, although the analogy between the organ of voice and the reed is just, the identity is not complete. The ordinary reeds are composed of rectangular laminæ; fixed at one side, but loose on the three others; whilst, in the larynx, the vibrating laminæ, which are also nearly rectangular, are fixed by three sides, and free by one only. Moreover, the tones of the ordinary reed can be made to rise or descend by varying its length; whilst in the laminæ of the larynx the width varies. Lastly—say they—in musical instruments, reeds are never employed, whose movable laminæ can vary in thickness and elasticity every moment, as is the case with the ligaments of the glottis; so that, although we may conceive, that the larynx can produce voice and vary its tones, in the manner of a reed instrument, we are unable to demonstrate the particulars of its mode of action.

All the more modern theories—detailed above, at more or less length—agree, then, in considering the larynx to be a wind instrument of the reed kind: they differ, chiefly in the *rôle* which they assign to the vocal tube in causing the variation of tones.[4]

M. Savart[5] has propounded a theory of voice, in which he differs from MM. Cuvier, Dutrochet, and Magendie. He denies, that the mechanism of the voice resembles that of the reed instrument, and returns to the old idea, which referred the vocal organ to an instrument of the flute kind. The sounds of the human voice have,—he remarks,—a peculiar character, which no musical instrument can imitate; and this must necessarily be the case, as they are produced by a mechanism founded on principles which do not serve as a basis in the construction of any of our instruments. He conceives that the production of the voice is analogous to that of the sound in the tube of a flute; and that the small

[1] Biot, Précis Élémentaire de Physique, p. 399.

[2] Precis, &c., i. 252.

[3] London and Edinburgh Philosophical Magazine, p. 205, for Sept. 1836.

[4] See, on all this subject, Mr. Bishop, art. Voice, in Cyclop. of Anat. and Phys., iv. 1483, Lond., 1852; and Emile Harless, art. Stimme, in Wagner's Handwörterbuch der Physiologie, iv. 505, Braunschweig, 1853.

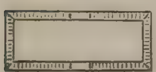
[5] Journal de Physiologie, v. 367, Paris, 1825; and Annales de Physique et de Chimie, xxx. 64, and xxxii.

column of air, contained in the larynx and mouth, by the nature of the elastic parietes which bound them, as well as by the mode in which it is thrown into vibration, is susceptible of rendering sounds of a particular nature, and, at the same time, much more grave than the dimensions would seem to permit.

In the tube of a flute, the column of air within is the sonorous body. A sound is first produced at the *embouchure* of the instrument, by the division which the air experiences when blown in; and this excites similar sonorous undulations in the column of air that fills the tube. The sound, resulting in this way, is grave in proportion to the length of the tube; and in order to vary its tones, the instrument has apertures in its sides, by means of which its length may be modified.

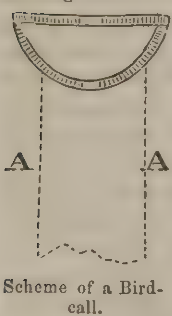
In assimilating the human vocal apparatus to a flute, the great difficulty has been to explain how, with so short a tube as the vocal tube in man, and one so little variable in length, tones so different, and especially so grave, can be produced. To account for this, M. Savart establishes a number of physical facts, previously unknown or unnoticed. In organ-pipes of great length, the velocity of the current of air, which acts as a motor, has but little influence on the number of oscillations. When the length of the pipe, for instance, is twelve or fifteen times greater than its diameter, it is difficult to vary the sound a semitone. When air is forcibly driven in, it rises an octave; and, when its velocity is diminished, the sound becomes more feeble; but is depressed an almost imperceptible quantity. In short pipes, on the contrary, the influence of the velocity of the current of air is much greater, and several tones can be elicited. The bird-call used by sportsmen is illustrative of this principle. It is a small instrument, employed for imitating the notes of certain birds, and consists of a cylindrical tube about three-fourths of an inch in diameter, and a third of an inch high, closed at each end by a thin, flat plate, which is pierced, at its centre, by a hole about the sixth of an inch in diameter. Sometimes it has the shape represented in the next marginal figure. By placing this instrument between the teeth and lips, and forcing air, with more or less strength through the two apertures, different sounds can be produced. This is more certainly effected, by attaching a *porte-vent* to the whistle, as A A, Fig. 390, when it is capable of producing all the sounds comprised in an extent of from an octave and a half to two octaves. M. Savart found, that, other things being equal, the diameter of the apertures has an appreciable influence on the acuteness or graveness of the sounds, which are graver the larger the orifices. The nature of the parietes of the instrument appeared, also, to exert some effect on the number of oscillations, and the quality of the sounds; and if, in the hemispherical whistle, Fig. 390, the plain plate was replaced by a thin leaf of some extensible substance, as parchment, the sounds issued more rapidly, and were usually more

Fig. 389.



Scheme of a Bird-call.

Fig. 390.



Scheme of a Bird-call.

grave, full, and agreeable, than when it was formed of a more solid substance.

It is an opinion generally admitted, that the material, which composes an organ-pipe, has no influence on the number of vibrations, which the column of air, contained in it, is capable of executing. This is true as regards long pipes; but, according to M. Savart, it is not so with short; and the nature of the *biseau*[1] he conceives, may have a great influence, even on the sound of long pipes. For instance, if we substitute, for the stiff lamina, which forms the *biseau* of an organ pipe two feet long and two inches on the side, a lamina, formed of some elastic substance, as skin or parchment, so arranged as to admit of being stretched at pleasure—by gradually increasing the tension of the membrane, at the same time that we increase the velocity of the current of air, the tone may be made to vary a fourth, and even a fifth. In shorter tubes, the much greater influence of the velocity of the current of air being united to that of the tension of the *biseau*, the result is still more evident. Thus, the sound of a cubical tube may be easily lowered an octave, when the parietes of the *biseau* are susceptible of different degrees of tension; but when all the parietes of a short pipe are of a nature to enter into vibration along with the air they contain, and when their degree of tension can be, moreover, varied, they have such an influence on the number of vibrations, that the sound may be greatly modified. Short tubes, open at both extremities, and formed of elastic parietes, are also susceptible of producing a great variety of sounds, even when they are only partly membranous; and the quality of the sound of membranous tubes is said to be somewhat peculiar,—partaking of that of the flute, and of the free reed. Again, in order that a mass of air shall enter into vibration, a sound must be produced in some part of it. In an organ pipe, for example, a sound is first excited at the embouchure, which throws the column of air, within the instrument, into vibration. Every sound, indeed, produced at the orifice of a column of air, throws it into vibration, provided its dimensions be adapted to the length of the waves produced directly:—hence the utility of a musical pipe having parietes susceptible of varying in size and tension, whatever may be the character of its *embouchure*. Lastly.—The fundamental note of a tube closed at one end, whose diameter is everywhere the same, is an octave lower than the sound of the same tube, when open at both extremities. But this is not the case with tubes that are of unequal diameter, conical and pyramidal, &c., when made to vibrate at their narrowest part. The tone produced in such case increases in graveness, according to the difference between its narrow and expanded portions.

These different physical conditions M. Savart invokes to account for the different tones of the human voice,—under the theory, that the vocal organ—composed of the larynx, pharynx, and mouth—forms a conical tube, in which the air is set in vibration by a movement similar to that which prevails in organ pipes. The trachea is terminated above by a cleft—the glottis—which is the inferior aperture of the

[1] The *biseau* or *languette* is the diaphragm placed between the body of an organ pipe and its foot.

vocal instrument. This cleft, which is capable of being rendered more or less narrow, plays the same part as the *lumière des tuyaux à bouche* or narrow space in the organ pipe, at the edge of the *biseau* or *languette*, along which the air passes. The air clears it, traverses the ventricles of the larynx or cavity of the instrument, and strikes the superior ligaments. These surround the upper aperture of the instrument, and fulfil the same function as the *biseau* of the organ pipe. The air, contained in the interior of the larynx, now vibrates, and sound is produced. This sound acquires intensity, from the waves that constitute it extending into the vocal tube above the larynx, and exciting in the column of air filling it a movement similar to that occasioned in the tube of a flute; except, that the tone is susceptible of much variation, because the larynx, being a short tube, can give rise to various tones by simple modification in the velocity of the air sent through it: moreover, the vocal tube has the same power, its parietes being membranous, of a vibratory nature, and capable of different degrees of tension. The inferior or outer part of the vocal tube is equally constituted of elastic parietes, susceptible of varied tension; and the mouth, by modifying the dimensions of the column of air within the tube, exerts an influence on the number of vibrations, which the column is capable of experiencing; whilst the lips can convert the channel at pleasure into an open or closed conical tube. Certain sounds, M. Savart affirms, are produced altogether in the ventricles of the larynx, those of pain, and the *falsetto* voice, for example. They can be elicited when the vocal tube has been removed; and there are animals, in which the vocal organ is reduced to the ventricles of the larynx,—frogs for example. Savart, consequently, considers, that the human vocal organ bears in its essential parts, C C, B B, Fig. 387, a striking analogy to the action of the bird-call; and, in this way, he explains the use of the superior ligaments C C, which are entirely overlooked in the different theories of the voice previously propounded.

We have given M. Savart's view at some length, in consequence of its ingenuity, and of its seeming to explain as well as any other theory the varied tones of which the human voice is susceptible. It cannot, however, be esteemed established, inasmuch as it is diametrically opposed, in many of its points, to the observations and vivisections of distinguished physiologists; who, it has been seen, affirm, that voice is produced solely by the inferior ligaments; that all the parts above these may be destroyed, and yet voice continue; and that a wound in the ventricles, which permits the exit of air through the parietes of the larynx, does not destroy the function. Our notions on this point must not, therefore, be considered definite. Farther experiments are necessary; and, in all deductions from them, great importance will have to be attached to the vital action of the organs, especially of the intrinsic muscles, which are capable of modifying the situation of parts, and the character of the function in myriads of inappreciable ways. It may be added, that Mr. J. Bishop,[1] from his numerous investigations, has arrived at the conclusion, that the human voice results from the vibration of membranous ligaments, in obedience, *first*, to the laws of musical

[1] Proceedings of the Royal Society, No. 65, Lond., 1847.

strings; *secondly*, to those of reed instruments; and *thirdly*, to those of membranous pipes; and that the vocal organs combine in reality the actions of each of these instruments, and exhibit in conjunction the perfect type of every one of them.

c. *Timbre or Quality of Voice.*

In the preliminary essay on sound, attached to the physiology of audition, it was remarked, that the cause of the different timbres of sound, in the various musical instruments, has hitherto remained unexplained. The same remark is applicable to the timbre of the voice. Each individual has his own, by which he is distinguished from those around him; and it is the same with each sex and period of life. In this the larynx is, doubtless, concerned; but in what manner is not clear. The feminine timbre or stamp, that characterizes the voice of the child and the eunuch, would appear to be generally connected with the cartilaginous condition of the larynx; whilst the masculine voice, which is sometimes met with in the female, is connected with the osseous condition of the parts, and especially of the thyroid cartilage. An infinity of modifications may also be produced by changes in the thickness, elasticity, and size of the lips of the glottis. The vocal tube probably exerts great influence in this respect by its shape, as well as by the nature of the material composing it. Such conditions, at least, appear to modify the timbre of our wind instruments. The timbre of a flute, made of glass or brass, is very different from that of one formed of wood, although the instruments may resemble each other in every other respect. The form of the body of the instrument has, also, considerable effect. If it be conical, and wider towards its outlet, as in the clarionet, or hautboy, the quality of the sound is shrill. If it be entirely cylindrical, as in the flute, we have the soft quality, which characterizes that instrument; and, on the other hand, if the tube be expanded at its middle portion, the quality of the sound is raucous and dull. It is probable, therefore, that we must reckon, amongst the elements of the varying character of the timbre or stamp of the voice, the different conditions of the vocal tube, as to length, width, and form; and that we must likewise include the position and shape of the tongue, of the velum palati, mouth and nose, the presence or want of teeth, &c., all which modify the voice considerably. The first modification takes place, probably, in the ventricles of the larynx, in which the voice acquires more rotundity and expansion. It was remarked by Dr. Isaac Parrish,[1] that a peculiar change was induced in two cases by the excision of the tonsils. The voice was rendered shrill and whistling.

By the generality of physiologists, it is conceived, that the voice enters the different nasal fossæ, and, by resounding in them, a timbre or character is given to it, which it would not otherwise possess. According to this view, when it is prevented from passing through the nose, from any cause, it acquires the *nasal* twang; or, by a singular inaccuracy of language, we are said "to talk through the nose." M. Magendie,[2] however, considers, that whenever the voice passes through

[1] Quarterly Summary of the Transactions of the College of Physicians of Philadelphia, Nov. and Dec., 1841, and Jan., 1842.

[2] Précis Élémentaire, i. 254.

the nasal fossæ, it becomes disagreeable and nasal. The simple experiment of holding the nose exhibits, that, in the enunciation of the true vocal sounds, unmodified by the action of the organs of articulation, the timbre or quality is materially altered; and we shall see, hereafter, that there are certain letters, that do not admit of enunciation, unless the nasal fossæ are pervious—the *m*, the *n*, and *ng*, for example. It would seem that, under ordinary circumstances, the sound, after it is produced in the larynx, flows out by both channels; and that, if we either shut off the passage through the nose altogether, or attempt to pass it more than usually through the nasal fossæ, the voice becomes *nasal*. The fine, sharp voice prior to puberty is especially owing to the narrowness of the glottis, the shortness of the ligaments, and according to M. Malgaigne,[1] the want of developement of the nasal cavities. At puberty, the size of the opening of the larynx is doubled; the ligaments enlarge, and the size of the passages of the nose is augmented. The timbre now becomes raucous, dull, and coarse; and for a time the harmony of the voice is lost. M. Bennati,[2] himself an excellent theoretical and practical musician, whose voice marks three octaves, advises, that the voice should not be much exerted during this evolution. He has known perseverance in singing at this time in several instances completely destroy the voice.

Not only does the voice, when produced in the larynx, pass out by the vocal tube, but it resounds along the tracheal and bronchial tubes, giving rise to the resonance or thrill, audible in certain parts of the chest, more especially, when the ear or the stethoscope is placed over them; and, when cavities exist in the lungs, in the consumptive, if the ear be placed upon the chest, immediately over one of them, the voice will appear to come directly up to the ear. The same thing happens, if the stethoscope be used. In this case, when the extremity of the instrument is applied over the vomica, the voice appears to pass directly through the tube to the ear, so as to give rise to what has been termed *pectoriloquy*. M. Adelon[3] conceives, that this distribution of the sound along the trachea or *porte-vent* and the lungs may suggest that the condition of these organs has some effect on the quality of the voice.

In speaking of the timbre of the voice in different individuals, we have had in view the natural quality,—not that which is the result of imitative action, and which can be maintained for a time only. Many of the conditions, which have been described as regulating the timbre, are voluntary, especially that of the shape of the vocal tube. In this way we can modify the timbre and imitate voices different from our own. The *table d'hôte* of many of the hotels of continental Europe is enlivened by the presence of individuals, capable of not only imitating various kinds of birds, but the timbres of different musical instruments; and the success which attended the personation of the voices of public speakers, by Matthews, Yates, and others, is sufficient evidence of the fidelity of their representations. We see the difference between the natural and imitative voice strongly exemplified in one of the

[1] Archives Générales de Médecine, pp. 201 and 214, Février, 1831.
[2] Recherches sur le Mécanisme de la Voix Humaine, Paris, 1832.
[3] Physiologie de l'Homme, edit. cit., ii. 204.

feathered songsters of our forests, *turdus polyglottis* or *mocking-bird*, which is capable of imitating, not only the voices of different birds, but sounds of other character, which cannot be regarded in the light of accomplishments.

There is a singular variety of the imitative voice, now employed only for purposes of amusement—but, of old, perhaps, used in the Pagan temples, by the priests, to infuse confidence in the oracular dicta of the gods—which requires notice; this is *engastrimism* or *ventriloquism*. Both these terms, by their derivation, indicate the views at one time entertained of its physiology, namely, that the voice of the ventriloquist is made to resound in the abdomen, in some inexplicable manner, so as to give rise to the peculiarity it exhibits. This singular view seems to have been once embraced by M. Richerand.[1] "At first," says he, "I had conjectured that a great part of the air expelled by expiration did not pass out by the mouth and nostrils, but was swallowed and carried into the stomach; and, being reflected in some part of the digestive canal, gave rise to a real echo; but, having afterwards more attentively observed this curious phenomenon on Mr. Fitzjames, who exhibits it in its greatest perfection, I was soon convinced that the name of ventriloquism is by no means applicable." M. Richerand was probably the last remnant of the supporters of the ancient vague hypothesis; and his views soon underwent conversion.

Another, equally unfounded notion, at one time entertained, was, that the ventriloquist possesses a double or triple larynx. It is now admitted, that the voice is produced at the ordinary place, and is modified in intensity and quality by actions of the larynx and vocal tube, so as to give rise to the deceptions we experience. It is known, that our appreciation of the distance and nature of a sonorous body is formed from the intensity and quality of the sound proceeding from it. We instinctively believe, that a loud sound proceeds from a near object, and a feeble sound from one more remote; accordingly, if the intensity and quality of the sound from a known body be such as to impress us with the idea that it is more remote than it really is, we incur an acoustic illusion. The ventriloquist takes advantage of this source of illusion; and, by skilfully regulating the force and timbre of his voice, leads us irresistibly into error. Mr. Dugald Stewart[2] gives some examples of this kind of illusion. He mentions having seen a person, who, by counterfeiting the actions of a performer on the violin, whilst he imitated the music by his voice, riveted the eyes of the audience on the instrument, although every sound they heard proceeded from his own mouth. Mr. Savile Carey, who imitated the whistling of the wind through a narrow chink, told Mr. Stewart, that he had frequently practised the deception in the corner of a coffee-house, and that he seldom failed to see some of the company rise to examine the tightness of the windows; whilst others, more intent on the newspapers, contented themselves with putting on their hats, and buttoning their coats.[3] It

[1] Élémens de Physiologie, édit. 13ème, par M. Bérard ainé, edit. Belge, cxciv. p. 300, Bruxelles, 1837.

[2] Elements of the Philosophy of the Human Mind, 3d edit., Lond., 1808; Amer. edit., Brattleborough (Vermont), 1813.

[3] Brewster, Natural Magic, Amer. edit., p. 158, New York, 1832.

is to account for the mode in which this is effected, that different hypotheses have been from time to time entertained. Haller, Nollet, Mayer,[1] and others, believed, that the voice is formed during inspiration; but this does not seem to be the case. Voice can certainly be effected during inspiration; but it is raucous, unequal, and of trifling extent only. MM. Dumas and Lauth[2] considered ventriloquism to be a kind of rumination of sounds; the voice, formed in the larynx, being sent into the interior of the chest, attaining there a peculiar timbre, and issuing of a dull character. M. Richerand is of opinion, that the whole mechanism consists in a slow, gradual expiration, which is always preceded by a deep inspiration. By means of this, the ventriloquist introduces into his lungs a considerable quantity of air, the exit of which he carefully regulates; and a similar view is embraced by Prof. J. Müller,[3] who asserts that the sounds uttered by the ventriloquists can be perfectly elicited by a method, which, he is convinced, must be adopted by them. This method consists in inspiring deeply so as to protrude the abdominal viscera by the descent of the diaphragm, and then speaking, whilst expiration is performed very slowly through a narrow glottis by means of the lateral parietes of the thorax alone, the diaphragm maintaining its depressed position; and M. Colombat confirms the general accuracy of Professor Müller's view, remarking that by continually practising in a manner somewhat similar to that pointed out by him he was enabled to attain considerable skill in the production of this variety of voice.[4] Mr. Gough[5] attempts to explain the phenomenon upon the principle of echoes;—the ventriloquist, he conceives, selects a room, well disposed for echoes in various parts of it, and produces false voices, by directing his natural voice in a straight line towards such echoing parts, instead of in a straight line towards the audience, who are supposed by Mr. Gough to be placed designedly by the ventriloquist on one or both sides of him. A sufficient answer to this is, that the practised ventriloquist is careless about the room chosen for his exhibitions; and habitually performs where this system of echoes would be totally impracticable.

But it is well to inquire what the ventriloquists themselves say of the mechanism of their art. We pass over the explanation of Baron von Mengen, an Austrian colonel, who forms a kind of vocal organ between his tongue and his left cheek, if we understand his description correctly, and keeps a reservoir of air in his throat to throw the organ into vibration. His object must evidently have been to mislead.

In 1811, M. L'Espagnol, a young physician, maintained a thesis on this subject before the *Faculté de Médecine* of Paris, which may be regarded as at least an honest exposition of his belief regarding the mode in which the phenomenon was effected in his own person. According to him, the whole is dependent upon the action of the velum pendulum palati. In ordinary voice, he remarks, a part of the sound

[1] Lepelletier, Physiologie Médicale, &c., iv. 213, Paris, 1833.
[2] Mémoir. de la Société des Sciences Agricol. de Strasbourg, i. 427.
[3] Elements of Physiology, by Baly, p. 1054, Lond., 1838.
[4] Baly and Kirkes, Recent Advances in the Physiology of Motion, the Senses, Generation and Developement, p. 11, Lond., 1848.
[5] Manchester Memoirs, 2d edit., v. 622, Lond., 1789.

passes directly through the mouth, whilst another part resounds in the nasal fossæ. If we are near the person who is speaking, these two sounds strike equally and almost synchronously upon the ear; but if at a distance from him, we hear only the first of the two sounds; when the voice appears more feeble, and, especially, has another timbre, which experience makes us judge to be that of the distant voice. The difference, says M. L'Espagnol, between the voice that proceeds from a near, and that from a more distant object is, that in the former we hear the mixture of the two sounds; whilst in the latter we hear that sound only, which issues directly from the mouth. Now, the secret of the ventriloquist is, to permit this direct sound only to pass to the ear, and prevent the nasal sound from being produced, or at least from being heard; and this is done by the elevation of the velum pendulum palati; the vocal sound does not then resound in the nasal fossæ; the direct sound is alone produced; the voice has the feebleness and timbre that belong to the distant voice, and is judged to proceed from a distance; and if, during the performance, it seems to come from any determinate place, it is owing to the ventriloquist attracting attention to it: the voice itself need only appear to proceed from a distance; and this it does more or less, according as the pendulous veil has more or less completely prevented the sound from issuing by the nasal fossæ. The ventriloquist thus, according to M. L'Espagnol, makes the voice appear nearer or more remote at pleasure, by raising or depressing the velum palati. He denies, that he speaks with his mouth closed; and affirms, that he articulates, but to a trifling extent only.

M. Comte, another ventriloquist, and of some celebrity, who has endeavoured to explain the physiology of his art, affirms, that voice takes place as usual in the larynx; but is modified by the action of other parts of the apparatus; that inspiration directs it into the thorax, where it resounds; and that both strength and flexibility are required in the organ to produce this effect. This, however, is no explanation. It is now universally admitted, that the voice of the ventriloquist is produced in the larynx; and that its character and intensity are modified by the action of other parts of the apparatus, but the particular agency that produces it is not elucidated by any of these attempted explanations of the ventriloquist.

About forty-five years ago (1810), Dr. John Mason Good,[1] in some lectures delivered before the Surrey Institution of London, suggested that the larynx alone, by long and dexterous practice, and, perhaps, by a peculiar modification in some of its muscles or cartilages, may be capable of answering the purpose, and of supplying the place of the associate organs of the mouth. In confirmation of this view, he remarks, that, in singing, the glottis is the only organ made use of, except where the notes are articulated; and it is apparently the sole organ employed in the mock articulations of the parrot and other imitative birds; some of which have exhibited unusual powers. The larynx, too, is the sole organ of all the natural cries; and hence it has been imagined by Lord Monboddo[2] to have been the chief organ of articulate language,

[1] Book of Nature, ii. 238, Lond., 1834; see also his Study of Medicine, Physiological Proem to Class ii., Amer. edit., i., 296, Philad., 1824.

[2] Origin and Progress of Language, i. 322, Edinb., 1773.

in its rudest and most barbarous state. "As all natural cries," he observes, "even though modulated by music, are from the throat and larynx, or knot of the throat, with little or no operation of the organs of the mouth, it is natural to suppose, that the first languages were, for the greater part, spoken from the throat; and that what consonants were used to vary the cries, were mostly guttural; and that the organs of the mouth would at first be but very little employed." Certain it is, that privation of the tongue does not necessarily induce incapacity of articulation; whether the defect be congenital, or caused after speech has been acquired. Professor John Thomson, of Edinburgh, found the speech but little impaired after bullets had carried away more or less of the tongue.[1] Under the Sense of Taste, several authentic cases were stated of individuals, who were deprived of this organ, and yet possessed the faculty of speech. To these we may add one other, which excited unusual interest at the time, and was examined under circumstances that could admit of no deception. The case forms the subject of various papers, by Dr. Parsons, in the Philosophical Transactions of London.[2] A young woman, of the name of Margaret Cutting, of Wickham Market, near Ipswich, in Suffolk, when only four years old, lost the whole of her tongue, together with the uvula, from a cancerous affection; she still, however, retained the power of speech, taste, and deglutition without any imperfection; articulating as fluently and correctly as other persons; and even those syllables that commonly require the aid of the tip of the tongue for accurate enunciation. She also sang admirably; articulating her words whilst singing; and could form no conception of the use of a tongue in other people. Her teeth were few; and rose scarcely higher than the surface of the gums, owing to the injury to the sockets from the disease that had destroyed the tongue. The case, when first laid before the Royal Society, was attested by the minister of the parish, by a medical practitioner of repute, and by another respectable individual. The Society, however, were not satisfied, and appointed commissioners to inquire into the case, whose report coincided minutely with the first; and, to set the matter completely at rest, the young woman was shortly afterwards conveyed to London, and examined, in person, before the Royal Society.[3]

These cases are not so extraordinary as they appear at first sight; when we consider, that the tongue is not the sole organ of articulation, but that it shares the function with the various parts that compose the vocal tube. In reality, of the twenty-five articulate sounds, which our common alphabet comprises, there are few in which the tongue takes a distinct lead, as *l*, *d*, *t*, *r*, &c., though it is auxiliary to several others; but the guttural or palatine, *g*, *h*, *k*, *q;* the nasal, *m*, and *n;* the labial, *b*, *p*, *f*, *v;* and most of the dental, together with all the vowels, are little indebted to its assistance.

From these, and other concurrent facts, Dr. Good[4] concludes, that

[1] Report of Observations made in the British Hospital in Belgium after the Battle of Waterloo, Edinb., 1816.
[2] Philosoph. Transact. for 1742 and 1747.
[3] Elliotson's Human Physiology, p. 507, Lond., 1840. See a curious chapter on the Use of Tongues in Southey, The Doctor, vii. i., Lond., 1847.
[4] Op. citat.

ventriloquism appears to be an imitative art, founded on a close attention to the almost infinite variety of tones, articulations, and inflexions, which the glottis is capable of producing in its own region alone, when long and dexterously practised upon; and in a skilful modification of these vocal sounds, thus limited to the glottis, into mimic speech, passed for the most part, and whenever necessary, through the cavity of the nostrils, instead of through the mouth. It is possible, he adds, though no opportunity has hitherto occurred of proving the fact by dissection, that they who learn this art with facility, and carry it to perfection, possess some peculiarity in the structure of the glottis, and particularly in respect to its muscles or cartilages. MM. Magendie[1] and Rullier,[2] however, affirm, that the quiescence of the lips, observed in the practised ventriloquist when enunciating, is more apparent than real; and that if he be capable of pronouncing without moving his lips, it is because he is careful to make use of words in which there are no labial consonants, or which do not absolutely require the movement of the lips in their formation. M. Rullier, indeed, denies positively, that the ventriloquist can speak without opening his mouth and moving his lips; but he affirms, that he uses his jaws, mouth, and lips, as little as possible in articulation; and he ascribes the common belief in their perfect quiescence to the habit, acquired by him, of restraining their movements, united to the care he takes in concealing them; and of giving to his face an impassive expression, or one foreign to the verbal expression to which he is giving utterance.

On the whole, the explanation of Dr. Good appears the most satisfactory:—the larynx or glottis affords some individuals a facility in acquiring the art, which others do not possess, in the same manner as it makes some capable of singing, whilst others are forever incapacitated. It is probable, however, that there may be a greater degree of obscure action about the parts composing the vocal tube than Dr. Good is disposed to admit; and that this may be materially concerned in giving the voice its peculiar quality and intensity; and eliciting some of the sounds which might not be so easily produced by the action of the glottis alone. Sir David Brewster[3] observes, that when the ventriloquist utters sounds from the larynx without moving the muscles of his face, he gives them strength by a powerful action of the abdominal muscles; and Bennati affirms, that he uses chiefly the pharyngeal voice, of which mention will be made under the head of *Singing*.

Such is the history of the simple voice, as effected in the larynx. Articulate sounds may, however, be produced in the vocal tube alone. *Whistling*, for example, is caused by the expired air being broken or divided by the lips, which act the part of the lips of the larynx in the production of voice.

Whispering consists in articulating the air of expiration. It is

[1] Précis, &c., i. 265.
[2] Art. Engastrimysme, in Dict. de Médecine, tom. viii., Paris, 1823.
[3] Letters on Natural Magic, p. 169, Amer. edit., New York, 1832.

wholly accomplished in the vocal tube; and, hence, the impracticability of singing in a whisper; singing being produced in the glottis.

The sound of *sighing* is produced by the rushing of air along the air passages, and especially along the vocal tube. In *laughing*, *crying*, and *yawning*, voice is concerned; but the physiology of these functions of expression will fall more appropriately under Respiration.

Having described the different views, that have been entertained, with regard to the production of voice, we shall now inquire into the function in connexion with expression. In this respect, it admits of division into the *natural* or *inarticulate voice*, and the *artificial* or *articulate.*

d. Natural or Inarticulate Language.

This, which is sometimes termed the *cry* or *native voice*, is an inappreciable sound, entirely produced in the larynx, and requiring few or none of the organs of articulation to aid in its formation. As, however, it is caused by different degrees of contraction of the intrinsic muscles of the larynx, it is susceptible of a thousand different tones. It is elicited independently of all experience or education; seems to be inseparably allied to organization; and, consequently, occurs in the new-born infant, the idiot, the deaf from birth, and the wild man, if any such there be, as well as in the civilized individual. The natural voice differs as much as the sentiments it is employed to express. Each moral affection has its appropriate cry;—the cry of joy is very distinct from that of grief;—of surprise from that of fear, &c.; and the pathologist finds, in the diseases of children more especially, that he can occasionally judge of the seat of a disease by the character of the cry, to which the little sufferer gives utterance; that there is, in the language of M. Broussais, a cry peculiar to the suffering organ.

By the cry, our vivid sensations are expressed, whether they be of the external or internal kind; agreeable or painful; and by it we exhibit all our natural passions, and most simple instinctive desires. Generally, the most intense sounds, to which the organ of voice can give utterance, are embraced in the natural cry; and, in its character, there is frequently something, that annoys the ear and produces more or less effect on those within hearing. It is, by its agency, that sympathetic relations are established between man and his fellows; and between animals of the same kind. The language, possessed by the greater part of animals, is this natural voice differing according to varying organization, and, therefore, instinctive; hence the various notes of birds; and the ranges, which we find the voice possess in different species. Yet each species has one, by which it is distinguished and which it possesses, even when brought up in the same cage with one of another species; or when hatched, and attended to, by a foster mother endowed with very different vocal powers. In the case of a goldfinch and chaffinch, this has been put directly to the proof; and it is well known, that the cuckoo, which is never hatched or nurtured by its own parent, still retains the note, that has acquired it its name in almost every language of the globe. It is, probably, by this natural cry, and not by any signs addressed to the eye, that the process of pairing is effected, and that the female is induced to select her mate.

The vocabulary of the common cock and hen is quoted as perhaps the most extensive of that of any tribe of birds with which we are acquainted; or rather, as Dr. Good remarks,[1] we are better acquainted with the extent of its range than with that of any other. The cock has his watchword for announcing the morning; his love-speech and terms of defiance. The voice of the hen, when leaving her nest, after laying, is different from that which she assumes when the brood is hatched, and both are very different from her cries, when her young are placed in jeopardy. Even the chick exhibits a variety in its voice, according to the precise emotion it experiences. All these sounds are such as the larynx of the animal alone admits of; and hence we can understand why, so far, they should be mere modifications of the natural voice; but it is more than probable, that the chick learns the adoption of a particular sound by the parent, to express a particular emotion, as an affair of education. It can scarcely be conceived, that the clucking of the hen, when she meets with food proper for her offspring, can be understood at first by the chick. But as soon as it traces the connexion between the sound produced and the object of such sound, it comprehends the signification ever afterwards.

There are sounds, which, from their discordant and harsh characters, affect most animals perhaps independently of all experience. The cry of terror or pain appears to occasion sympathetically disagreeable effects on all that are within its sphere.

e. Artificial or Articulate Language.

Speech, likewise, is a vocal sound; but it is articulated, in its passage through the vocal tube; and is always employed to convey ideas, that have been attached to it by the mind. It is a succession of articulate sounds, duly regulated by volition, and having determinate significations connected with them.

The faculty of speech has been assigned by some philosophers chiefly to the organ of hearing. It is manifest, however, that this, like the musical ear, is referable to a higher organ. The brain must attach an idea to the impression made upon it by the sounds that impinge upon the organ of hearing; the sound thus becomes the *sign* of such idea, and is reproduced in the larynx at the will of the individual. Of the intellectual character of the process, we have decisive evidence. The infant of tender age has the ear and voice well developed, yet it is long before it is capable of speech; this does not happen until it discovers the meaning of the sounds addressed to it, and finds its own larynx capable of producing similar sounds, which can be made subservient to its wishes. It is thus, by imitation, that it acquires the faculty of speech. Again, the idiot, notwithstanding his hearing may be acute, and voice strong, is incapable of speech; and, in the maniacal and delirious, the language participates in the derangement and irregularity of ideas. The brain must, therefore, be regarded as the organ of the faculty of language; and the ear, larynx, and vocal tube as its instruments. Man, who is endowed with the most commanding intellect, has the vocal apparatus happily organized for expressing its

[1] Book of Nature, ii. 277, Lond., 1826.

various combinations; and, according to Gall, if the ourang-outang and other animals are incapable of speech, it is because they have not the intellectual faculty of language. In proof, that it is not to the vocal organ that this deficiency must be ascribed, he remarks, that animals may be made to enunciate several of the words of human speech, and to repeat them with music. The case of the far-famed parrot of Colonel O'Kelly is familiar to many. Mr. Herbert[1] saw this parrot, about the year 1799: it then sang perfectly about fifty different tunes, solemn psalms, and humorous or low ballads; articulating every word as distinctly as man, without a single mistake; beating time with its foot; turning round upon its perch, and marking the time as it turned. If a person sang part of a song it would take it up where he left off; and when moulting and unwilling to sing, turned its back and said, "Poll's sick." Gall, amongst other cases, cites that of a dog mentioned by Leibnitz, which could articulate some German and French words. This dog, of which Leibnitz was an "eye-witness," was at Zeitz, in Misnia. A young child had heard it utter some sounds, which it thought resembled German, and this led him to teach it to speak. At the end of about eight years, it had learned thirty words, some of which were, *tea*, *coffee*, *chocolate*, and *assembly*. It spoke only after its master had pronounced the word, and appeared to do so only on compulsion, although it was not ill used.[2] In the "Dumfries Journal," Scotland, for January, 1829, mention is made of a dog, then living in that city, which could utter distinctly the word "William," the name of the young man to whom it was much attached.[3] There is no doubt, however, that in numerous animals speech would be impracticable, owing to defective organization, even were they gifted with adequate intellect.

It is difficult—perhaps impossible—to say, how man came to select certain sounds as the types of certain intellectual acts; nor is it a matter which strictly concerns the physiologist. It may be remarked, however, that whilst some contend, that speech is a science which was determined upon, and inculcated, at an early period of the world, by one or more superior persons acting in concert, and inducing those around them to adopt their articulate and arbitrary sounds; others affirm, that it has grown progressively out of the natural language, as the increasing knowledge and wants of mankind demanded a more extensive vocabulary.[4] The first view is that of Pythagoras and Plato; but it was opposed by Lucretius and the Epicureans, on the ground, that it must have been impossible for any one person or synod of persons to invent the most difficult and abstruse of all human sciences with the paucity of ideas, and of means of communicating them, which they must have possessed; and that even allowing they could have invented such a science, it must still have been utterly impossible for them to teach it to the barbarians around them.

The opinions of those philosophers who confine themselves to the

[1] In a note to the Rev. Gilbert White's Natural History of Selborne, p. 227.

[2] Letter to the Abbé Saint Pierre, Oper. ii. 180.

[3] Sharon Turner, Sacred History of the World, p. 280, Amer. edit., New York, 1832.

[4] Harris, Hermes, 3d edit., Book iii., p. 314, London, 1771; Beattie, Theory of Language, p. 246, London, 1803, and Good, Book of Nature, ii. 254, London, 1834.

phenomena of nature, and hold themselves uncontrolled by other authority, accord with those of the Epicureans.

In the origin of language, it is probable, that words were suggested to mankind by sounds heard around;—by the cries of quadrupeds;—notes of the birds of the forest;—noises emitted by the insect tribe;—audible indications from the elements, &c. These, being various, probably first of all suggested discriminative names, deduced from the sounds heard. It is this imitation of the noise made by objects, that constitutes the figure of speech called *onomatopœia*,—the "*vox repercussa naturæ*" or "echo of nature," as Wachter[1] has defined it. Daily experience shows us, that this source of words is strictly physiological. Children designate a sonorous object by an imitation of the sounds rendered by it; and the greater number of sonorous bodies have had names, radically similar, given to them in languages differing most from each other. We say the serpents "*hiss;*" the bees "*hum;*" the storm "*blusters;*" the wind "*whistles;*" the hogs "*grunt;*" the hen "*cackles*," the man "*snores*," &c., words used, originally, not perhaps in these very shapes, but varying according to the varying idiom of language, to imitate the sounds elicited by those objects. Such words are numerous in all languages, and have been adopted to depict both the sound emitted, and the sonorous body itself; but, in some cases, the word imitating the sound has survived its transmission from language to language to the most modern times, whilst the name of the object whence it proceeded has experienced considerable mutation. The Sanskrit, the antiquity of which will not be contested, has a number of such words—as *wilala*, cat—*kukada*, hen—and *waihu*, wind; in the last of which the sound of the *w* (*oo*), imitates that of the passage of the air, and is found in the word corresponding to *wind* (*ooind*,) in many languages. The Hebrew and the Greek have numerous phonetic words; but no language is richer, in this respect, than the Teutonic in all its ramifications, including the English. The animal kingdom affords us many examples, of which the following is one:—

Cuckoo.—This word is nearly the same in almost all languages. Greek, κοκκυξ; Latin, *cucullus;* Irish, *cuach;* Bask, *cucua;* Sclavonic, *kukulka*, *kukuscka*, &c.; Hungarian, *kukuk;* Hebrew, *cacatha;* Syriac, *coco*; Arabic, *cuchem;* Persian, *kuku;* Koriak, *kaikuk;* Kamtschadale, *koakutschith;* Kurile, *kakkok;* Tartar, *kauk;* German, *kuckucks* or *guckguck;* Dutch, *koekoek;* whence our words *cuckoo* and *cuckold*, and the Scottish *gouckoo*, *gowk*, or *golk;* French, *cocu;* &c.

In the greater part of languages, words, expressive of the cries of animals, are accurate imitations. Of this, the following are a few examples.

Bleating of sheep.—Greek, βληχαομαι; Latin, *balare;* Italian, *belare;* Spanish, *balar;* French, *beler;* German, *blöken;* Dutch, *bleeten;* Saxon, *blætan*, &c.

Howling of wolves.—Greek, ὀλολυζω; Latin, *ululare;* German, *heulen;* Dutch, *huilen;* Spanish, *aullar;* French, *hurler*, &c. Hence the word *owl.*

Neighing of the horse.—Latin, *hinnire;* French, *hennir;* German, *wiehern;* Saxon, *hnægan*, &c.

Clocking or *clucking* of hens.—Latin, *glocire;* French, *glousser;* Greek, κακκαζειν; German, *glucken;* Dutch, *klokken;* Saxon, *cloccan*, &c.

To *crow*, like a cock.—Greek, κραζω; German, *krähen;* Dutch, *kraayen;* Saxon, *craw*, &c., whence the word *crow*, the bird.

[1] Glossarium Germanicum, Lips., 1737.

The Latin words *tinnimentum*, *tinnitus*, *tintinnabulum*, &c., from *tinnio*, "I ring," are all from the radical *tin*, and imitate the sound rendered on striking a metallic vessel. The *gurgling* of water; the *clanging* of arms; the *crash* of falling ruins; are of the same character; and the game *trictrac*, formerly *tictac*, seems to have been so called from the noise made in putting down the men or dice.[1]

In whatever manner language was first formed, it is manifest that the different sounds could make but transient impression, until they were reduced to legible characters, which could recall them to mind. On our continent, the fact has often been noticed of a tribe of Indians separating themselves into two parties, and remaining distinct for years. In such case, the language has become so modified, that after the lapse of a considerable period they have scarcely been able to comprehend each other. Hence, the importance of the art of writing,—certainly the most valuable of human inventions. Of this, there have been two kinds, *imitative* or *alphabetical*,—and *symbolical*, *allegorical*, or *emblematical*, the latter consisting of hieroglyphics, designs representing external objects, or symbolical allegories. The former, or the written representation of spoken sounds, alone concerns us. To attain this, every compound sound has been reduced to certain elementary sounds, which are represented by signs, called *letters*. These elementary sounds, by combination, form *syllables;* and the syllables, by combination, *words*. The number of elementary sounds, admitted in each language, constitutes its *alphabet*, which differs more or less in certain languages; but as it is entirely a matter of human invention, and as the elementary sounds, of which the human voice is capable, are alike in the different races of mankind, we see readily, that the alphabets of the different languages must correspond, although the combinations of letters constituting syllables and words may vary essentially.

Into the origin of written legible language, it is not necessary to inquire. We may remark, that the invention has been considered so signally wonderful as to transcend human powers; and hence, St. Cyril, Clement of Alexandria, Eusebius, Isidore, and, in more modern times, Messrs. Bryant, Costard, &c., have been of opinion, that the knowledge of letters was first communicated to Moses by the Almighty himself, and that the decalogue was the earliest specimen of alphabetic writing. Many passages in the writings of Moses show unequivocally, however, that written records must have existed prior to his time. In the passage in which writing is first mentioned in the sacred volume, the art is alluded to as one of standing:—"And the Lord said unto Moses, 'Write this for a memorial in a book or table;'" and in a subsequent chapter—"And thou shalt make a plate of pure gold, and grave upon, like the engravings of a signet, Holiness to the Lord."[2]

The English alphabet is considered to consist of twenty-six letters. It may, however, by ultimate analysis, be reduced to twenty-five simple sounds—A, B, D, E, F, G, H, I, J, K, L, M, N, O, P, R, S, T, U, V, Z, Ch, Sh, Th, and Ng. To these letters arbitrary names have

[1] See De Brosses, Traité de la Formation Méchanique des Langues, &c., i. 232, Par. An. ix.

[2] Good, op. citat., ii. 273.

been assigned, as *Bee* (B,) *See* (C,) *Dee* (D,) &c., which express very different sounds from those that belong to the letter when it forms part of a word or syllable. The word *bad* is not pronounced *bee-a-dee*, as the child, just escaped from learning his alphabet, must imagine; hence, he has to unlearn all that he has acquired; or to imagine, that different letters have very different sounds, according to the situation in which they are placed. To obviate this inconvenience, some persons are in the habit of teaching their children syllabically from the very first, by which they acquire the true sound attached to each letter of the alphabet.[1] In the preceding enumeration of the simple sounds, that constitute the alphabet, C, Q, W, X, and Y, have been excluded, for the following reasons. C has always the sound of either S or K, as in *cistern* or *consonant*. Q has the sound of *koo*, as in quart, (*kooart;*) W of *oo*, as in word (*oourd;*) X of *ks*, or Z, as in vex, (*vecks,*) or Xerxes, (*zerkses;*) whilst Y has the sound of I or E, as in wry or yard, (*ri* or *eeard.*) *Ch*, *Sh*, and *Th*, have been added, as being true alphabetic or simple sounds.

Letters have been usually divided into two classes, *vowels* and *consonants.* The *vowels* or *vocal sounds* are so called, because they appear to be simple modifications of the voice formed in the larynx, uninterrupted by the tongue and lips, and passing entirely through the mouth. Such at least is the case with those that are reckoned *pure vowels.* These, in the English alphabet, are five in number,—A, E, I, O, and U. W and Y are, likewise, vowel sounds in all situations. In enunciating A, as in *fate*, the tongue is drawn backwards and slightly upwards, so as to contract the passage immediately above the larynx. In sounding E, the tongue and lips are in their most natural position without exertion. I is formed by bringing the tongue nearly into contact with the bony palate; O, by the contraction of the mouth being greatest immediately under the uvula, the lips being also somewhat contracted. In the production of U, the contraction is prolonged beneath the whole of the soft palate. From these principal vowels, all the other vowel sounds of the language may be formed, by considering them as partaking more or less of the nature of each. They are, in our language, fourteen in number: besides compound sounds, as in *oil* and *pound.* Of these fourteen, four belong to A; two to E; two to I; three to O; and three to U.

A, as in . . .	Fate. Far. Fast. Fall.	O, as in . . .	No. Not. Move.
E, as in . . .	Me. Met.	U, as in . . .	Tune. Tub. Bull.
I, as in . . .	Pine. Pin.		

[1] Both Lord Stowell and Lord Eldon received the rudiments of their education from Mr. Warden, an approved master of the day, long remembered in Newcastle by the name of Dominie Warden. "His manner of teaching to read had this peculiarity, that instead of sounding each consonant with an auxiliary vowel, as B be, F ef, K ka, and so forth, he confined the expression of each consonant to its own almost mute sound, as B, F or K. This mode of *muffling* the consonants is said to have been very successful with the learners." The Public and Private Life of Lord Chancellor Eldon, by Horace Twiss, Esq., i. 30, Lond., 1844.

The vowels are more easy of pronunciation than the consonants. They merely require the mouth to be opened; and howsoever it may be arranged in the enunciation of the different vowels, the vocal tube is simply modified, to vary the impression which has to be made on the organ of hearing. The shape of the cavity is altered; but the passage of the air continues free, and the voice, consequently, issues in an unrestrained manner. Hence, perhaps, the physiological origin of the Danish word *Aa*, "a river"—a generic term, which became afterwards applied to three rivers in the Low Countries, three in Switzerland, and five in Westphalia,—the sound of the two broad A's flowing without obstacle, like a river. Time passes away in a similar manner; hence, for a like reason, the Greek ἀεὶ which signifies "always, perpetually;" and the German je, which has the same signification.

The consonants are more difficult of enunciation than the vowels; as they require different, and sometimes complex, and delicate movements of the vocal tube; and, on this account, they are not acquired so early by children. The term *consonant* is derived from one of its uses,—that of binding together vowels, and being sounded with them. By most, and according to Mr. Walker,[1] by the best grammarians, *w* and *y* are consonants when they begin a word; and vowels when they end one. Dr. Lowth,[2] however, a man of learning and judgment, who certainly would not suffer in a comparison with any of his opponents, regards them, as the author does, to be always vowels. Physiologically, it is not easy to look upon them in any other light. Yet Mr. Walker exclaims:—"How so accurate a grammarian as Dr. Lowth could pronounce so definitely on the nature of *y*, and insist on its being always a vowel, can only be accounted for by considering the small attention which is generally paid to this part of grammar." No stronger argument, however, could be used against the useless expenditure of time on this subject, than the conclusion to which Mr. Walker himself has arrived; and for which he can find no stronger reasons, than that "if *w* and *y* have every property of a vowel, and not one of a consonant; why, when they begin a word, do they not admit of the euphonic article *an* before them?"!

The consonants are usually divided into *mutes*, *semi-vowels*, and *liquids*. Mutes are such as emit no sound without a vowel,—*b*, *p*, *t*, *d*, *k*, and *c* and *g* hard. *Semi-vowels* are such as emit a sound, without the concurrence of a vowel, as *f*, *v*, *s*, *z*, *x*, *g* soft or *j*. *Liquids* are such as flow into, or unite easily with, mutes, as *l*, *m*, *n*, *r*. These letters issue without much obstacle; hence perhaps their name.

In tracing the modes in which the different consonants are articulated, we find that certain of them are produced by an analogous action of the vocal tube; so that the physiology of one will suffice for the other. For instance, the following nearly correspond:—

p	*f*	*t*	*s*	*k*	*ch*
&	&	&	&	&	&
b	*v*	*d*	*z*	*g*	*j*

B and P are produced when the lips, previously closed, are suddenly opened. B differs from P in the absence, in the latter, of an accom-

[1] Preface to his Dictionary. [2] Introduction to English Grammar, p. 3.

panying vocal sound. F and V are formed by pressing the upper incisor teeth upon the lower lip. They are, consequently, not well enunciated by the aged, who have lost their teeth. F differs from V only in the absence of an accompanying vocal sound. T and D are formed by pressing the tip of the tongue against the gums behind the upper incisor teeth. D is accompanied by a vocal sound; T not. S and Z are produced by bringing the point of the tongue nearly in contact with the upper teeth, and forcing the air against the edges of the teeth with violence. S differs from Z in the absence of the vocal sound. K and G are formed by pressing the middle of the tongue against the roof of the mouth, near the throat; separating the parts a little more rapidly to form the former, and more gently to form the latter of those letters. In K, the accompanying vocal sound is absent. Ch and J are formed by pressing *t* to *sh;* and *d* to *zh.* In Ch, there is no accompanying vocal sound. SH and ZH are formed in the same part of the tube as *s* and *z.* TH is formed by protruding the tongue between the incisor teeth, and pressing it against the upper incisors to produce its sound in *think.* Its sound in *that* is effected by pressing the tongue behind the upper incisor teeth. In the former case, it is unaccompanied by a vocal sound. In M, the lips are closed, as in B and P; and the voice issues by the nose. N is formed by resting the tongue against the gums, as in the enunciation of *t* and *d;* breathing through the nose with the mouth open. In L, the tip of the tongue is pressed against the palate, the sound escaping laterally. In forming the letter K, the middle and point of the tongue strike the palate with a vibratory motion; the tip being drawn back. Lastly, in the formation of H, the breath is forced through the mouth, which is everywhere a little contracted. It need hardly be said, that the enunciation of these letters requires, that the vocal tube, or the parts concerned in the function, shall be in a sound condition.[1]

A few years ago (1846), an ingenious German, named Faber, exhibited publicly in Philadelphia a speaking automaton, which he subsequently, in England, called "Euphonia or Speaking Automaton,"[2] in the construction of which he found that the alphabet can be simplified still further. The precise mechanism he did not unfold; but affirmed that the parts were made of elastic materials to resemble as nearly as possible the human vocal organs. These parts were susceptible of varied movements by means of keys. The author was much struck by the distinctness with which the automaton could enunciate various letters and words. The combination *three* was well pronounced; the *th* less perfectly; but astonishingly well. It also enunciated diphthongs and numerous difficult combinations of sounds. Sixteen keys were sufficient to produce all the sounds. It sang "God Save the Queen" and "Hail Columbia"—the words and air combined.

The following is the alphabet of the automaton. 1. *Five simple vowels:* for example—*a* as in father; *o* as in home; *u* as in ruin; *i* as *e*, and *e* as *a*. 2. *Nine consonants*, *l*, *r*, *w* (the German w—the English w is oo),

[1] Mayo, Outlines of Human Physiology, 3d edit., p. 357, Lond., 1833; also, Haller, Element. Physiol., lib. ix. § 4, Lausann., 1766.

[2] J. Bishop, On Articulate Sounds and on the Causes and Cure of Impediments of Speech, p. 24, London, 1851.

f, *s*, *sh* in shall, and *b*, *d*, *g* hard, as in give. 3. A *nasal sound* and an *aspirate;* making in all sixteen simple sounds. From these the *compound sounds* are formed, as in the following examples: *b* and the *nasal* form *m; d* and the *nasal*, *n:* if the nasal sound be prevented, *me* becomes *be; not* becomes *dot; g* and the *nasal* form *ng; b* and the *aspirate* form *p; d* and the *aspirate*, *t; g* and the *aspirate*, *k; sh* and the *nasal*, *th; wf* or *uf* form *v; d* and *sh*, *j* and *g soft; t* and *sh*, *ch* in chin. The diphthongs admitted by Mr. Faber are *ai* i, *eu* u, and *au* sounded as in *how*.

Wolfgang von Kempelen,[1] in a work on the mechanism of human speech, which is considered classical in Germany,—and in which he treats of a speaking automaton (Sprachmaschine) of his invention,—divides the consonants into four classes. 1. *Mutes* (ganz stumme), as K, P, T. 2. *Explosives* (Windmitlauter), as F, H, Ch, S, and Sh. 3. *Vocal consonants* (Stimmitlauter), as B, D, G, L, M, and N; and 4. *Vocal explosives* (Wind und Stimmlauter zugleich), as R, I, W, V, Z. Dr. Thomas Young has, likewise, divided the English consonants into classes; of which he enumerates five. 1. *Pure semi-vowels*, as L, R, V, Z, and J. 2. *Nasal semi-vowels*, as M and N. 3. *Explosive letters*, as B, D, and G. 4. *Susurrant letters*, as H, F, X, and S; and 5. *Mutes*, as P, T, K; but the most satisfactory classification, in a physiological, as well as philological point of view, is according to the parts of the vocal tube more immediately concerned in their articulation.

Labial.	Dento-labial.	Linguo-dental.	Linguo-palatal.	Guttural.
B M P	F V	Th	D J L N R S T Z Ch Sh Ng	G K

That this physiological arrangement has had much to do with the formation of congenerous tongues more especially is exhibited by facts connected with the permutation or change of letters;—when a word passes, for example, from one of the Teutonic or Romanic languages to another. "The changes of vowels," says Mr. Lhuyd,[2] "whether by chance or affectation, are so very easy and so common in all languages, that in etymological observations, they need not, indeed, be much regarded; the consonants being the sinews of words, and their alterations therefore the most perceptible. The changes of consonants also into others of the same class, (especially *labials*, *palatals*, and *linguals*,) are such obvious mistakes, that there is no nation where the common people in one part or other of their country do not fall into some of them." A few examples will show to what extent this permutation occurs between letters of the same class in different languages. In this view, we may regard the labials and dento-labials as belonging to the same.

P into B.—Greek, φλέψ; Latin, *phlebs*. Latin, (and Greek,) *episcopus;* English, *bishop;* Anglo-Saxon, *biscop;* German, bischof.

P into F and V.—Latin, *pater;* German, vater; Dutch, *vader;* English, *father*.

[1] Mechanismus der menschlichen Sprache, S. 228, Wien, 1791; and Rudolphi, Grundriss der Physiologie, 2ter Band, 1ste Abtheil., S. 398, Berlin, 1823.

[2] Archæologia Britannica, Oxford, 1707.

T into S.—German, besser; English, *better*. German, wasser; English, *water*.
D into Th.—German, das: Dutch, *dat*; English, *that*.
T into Z.—German, zung; Dutch, *tong*; English, *tongue*. German, zweig; English, *twig*.
L into R.—Spanish, *Gil Blas*; Portuguese, *Gil Bras*. Latin, *arbor*; Spanish, *albero*.
C or K into G.—Latin *hemicranium*; French, *migraine*. Latin, *cibarium*; French, *gibier*. Latin, *acer*; Italian, *agro*. Latin, *alacer*; Italian, *allegro*. Greek, κυκνος; Latin, *cygnus*.

The most harmonious languages are such as have but few consonants in their words, compared with the number of vowels; hence the musical superiority of the Greek and Italian, over the English, German, &c. "Among certain northern nations," says M. Richerand,[1] "all articulated sounds appear to issue from the nose or the throat, and make a disagreeable pronunciation, doubtless because it requires greater effort; and he who listens, sympathizes in the difficulty, which seems to be felt by him that speaks;"—and he adds:—"would it not seem that the inhabitants of cold countries have been led to use consonants rather than vowels, because as the pronunciation does not require the same opening of the mouth, it does not afford the same space for the continual admission of cold air into the lungs?"! The whole of Richerand's remarks on this topic are singularly fantastic and feeble, and unworthy of serious discussion.

In regard to consonants, it has been presumed, that some common imitative principle must have existed with all nations, so as to cause them to conform in adopting such as produce a certain sound to convey the same effect to the ear. Dr. John Wallis[2] turned his attention to this matter, chiefly as regards the English language, and he has collected a multitude of examples to show, that a certain collocation of consonants at the commencement of a word generally designates the class of ideas intended to be conveyed by it. For instance, he remarks that:—

Str, always carries with it the idea of *great force* and *effort*—as *strong*, *strike*, *stripe*, *strife*, *struggle*, *stretch*, *strain*, &c.
St, the idea of strength, but in less degree—the *vis inertiæ*, as it were:—as *stand*, *stay*, *stop*, *stick*, *stutter*, *stammer*, *stumble*, *stalk*, *steady*, *still*, *stone*, &c.
Thr, the idea of violent motion:—as *throw*, *thrust*, *throb*, *threat*, *throng*, &c.
Wr, the idea of obliquity or distortion:—as *wry*, *wreathe*, *wrest*, *wring*, *wrestle*, *wrench*, *wriggle*, *wrangle*, &c.
Br, the idea of violent—chiefly sonorous—fracture or rupture:—as *break*, *brittle*, *brust*, or burst, *brunt*, *bruise*, *broil*, &c.
Cr, the idea of straining or dislocation, chiefly sonorous:—as *crack*, *creak*, *crackle*, *cry*, *crow*, *crisp*, *crash*. Other words, beginning with these consonants, communicate the idea of curvature, as if from *curvus*:—as *crook*, *cringe*, *crouch*, *creep*, *crawl*, *cripple*, *crumple*, *crotchet*, &c. Others, again, denote decussation, as if from *crux*:—as *cross*, *cruise*, *crutch*, *crosier*.
Shr, the idea of forcible contraction:—as *shrink*, *shrivel*, *shrug*, *shrill*, &c.
Gr, the idea of the rough, hard, onerous and disagreeable, (either owing to the letter of roughness *r*, or from *gravis*,)—as *grate*, *grind*, *gripe*, *grapple*, *grieve*, *grunt*, *grave*, &c.
Sw, the idea of silent agitation or of gentle lateral motion:—as *sway*, *swag*, *swerve*, *sweat*, *swim*, *swing*, *swift*, &c.
Sm, a very similar idea to the last:—as *smooth*, *small*, *smile*, *smirk*, &c.
Cl, the idea of some adhesion or tenacity:—as *cleave*, *clay*, *cling*, *climb*, *cloy*, *cluster*, *close*, &c.
Sp, the idea of some dispersion or expansion, generally quick, (especially with the addition of the letter *r*,) as *spread*, *spring*, *sprig*, *sprinkle*, *split*, *splinter*, *spill*, &c.

[1] Élémens de Physiologie, edit. cit., p. 298.
[2] Grammatica Linguæ Anglicanæ, &c., edit. 6, Lond., 1765.

Sl, the idea of a gently gliding or slightly perceptible motion:—as *slide, slip, slippery, slime, sly, slow, sling*, &c.

Lastly: *Sq, Sk, Scr*, denote violent compression:—as *squeeze, squirt, squeak, squeal, skreek, screw*, &c.

Other interesting observations on the collocation of consonants, at the termination, and in the body, of words, are contained in the grammar of Wallis. His remarks, however, are chiefly confined to his own tongue. The President de Brosses[1] has taken a wider range, with a similar object, and endeavoured to discover why certain consonants, or a certain arrangement of consonants in a word, should designate certain properties in all languages. Why, for instance, the *st* should enter into most words signifying firmness and stability:—as, in the Sanskrit, *stabatu*, to stand, *stania*, a town, &c.; in the Greek, στηλη, a column, στερεος, solid, immovable, στειρα, sterile, remaining constantly without fruit, στηριζω, "I fix firmly," &c.; in the Latin, *stare*, to stand; *stirps*, a stem; *stupere*, to be astonished; *stagnum*, stagnant water, &c.; and he might have added, in the German, still-stehend, stagnant; stadt, a town; stand, condition; sterben, to die; still-stand, cessation, &c., besides the English words, commencing with *st*, already quoted from Wallis. He farther inquires, why words, commencing with *sc*, denote hollowness, as σκαπτω, I dig; σκαφη, skiff or boat, in the Greek; *scutum*, a shield; *scyphus*, a large jug; *sculpere*, to engrave; *scrobs*, a ditch, in the Latin;—*ecuelle*, formerly *escuelle*, a dish; *scarifier*, to scarify; *scabreux*, scabrous; *sculpture*, &c., in the French; and many similar words might be added from our own language. *Ecrire*, formerly *escrire*, the French for "to write" is from the Latin *scribere:* and, anciently, a kind of style was used for tracing the letters in wax; which instrument, by a like analogy, was called by the Greeks, σκαριφος. M. de Brosses[2] accounts for these, by supposing, that the teeth, being the most immovable of the organic apparatus of the voice, the firmest of, what he calls the dental letters, T, has been mechanically employed to denote stability; and to denote hollowness, the K or C has been adopted,—which are produced in the throat, the most hollow of the vocal organs. The letter S serves, he conceives, merely as an augmentative; as the sound can, by its addition, be made continuous. It is itself, however, a letter expressive of softness, when combined, as we have seen, with certain other consonants; or when employed alone at the commencement of a word.

In the same manner, the letters *fl* are used to designate the motion of fluids more especially,—as in the Greek, φλοξ, a flame; φλεψ, a vein; Φλεγεθων, a burning river in the infernal regions:—in the Latin, *flamma*, flame; *fluo*, I flow; *flatus*, wind; *fluctus*, wave, &c.;—in the German, flössen, to float; flöten, to play on the flute; fluss, a river; flug, flight, &c.; and in the French and English words of the same meaning. Lastly, the idea of roughness and asperity is conveyed by the letter *r*, as in the words *rough, rude, rock, romp*, &c. How different, for example, in smoothness are the two following lines, in which the S

[1] Traité de la Formation Méchanique des Langues et des Principes Physiques de l'Étymologie, i. 238, Paris, An ix.

[2] Op. cit., i. 261.

predominates, from those that succeed them, where the R frequently, and perhaps designedly, occurs:

> "Softly sweet in Lydian measures,
> Soon he soothed his soul to pleasures;"

And:—

> "Now strike the golden lyre again,
> A louder yet, and yet a louder strain;
> Break his bands of sleep asunder;
> And rouse him like a rattling peal of thunder."
>
> DRYDEN'S "*Alexander's Feast.*"

The foregoing remarks, suggested by those of Wallis and M. de Brosses, must not, however, be received too absolutely. In the condition in which we find languages at the present day, it would be impossible that they should hold good universally; but they will tend to show, that the physiology of the voice is intimately connected with this part of philology; and that the sounds emitted by the agency of particular parts of the vocal tube, may have led to the first employment of those sounds, according to the precise idea it may have been desired to convey;—gutturals, for example, for sounds conveying the notion of hollowness;—resisting dentals, that of obstacles, &c. The words *mamma* and *papa* are composed of a vowel and consonant, which are the easiest of enunciation; and which the child, consequently, pronounces and unites earlier than any other. Hence they have become the infantile appellations for *mother* and *father* with many nations. President de Brosses[1] affirms—and he has brought forward numerous examples to prove his position—that in all ages, and in every country, a labial, or, in default of it, a dental, or both together, are used to express the first infantile words "papa" and "mamma;" but it is scarcely necessary to say, that the child, when it first pronounces the combinations, attaches no such meaning to them as the parent fondly imagines.

There is a rhetorical variety of onomatopœia, frequently considered under the head of *alliteration*, but by no means deriving its chief beauties from that source. It happens when a repetition of the same letter concurs with the sonorous imitations already described; as in the following line in one of the books of the Æneid of Virgil;—

> "Luc*t*an*t*es ven*t*os *t*empes*tat*esque sonoras,"

in which the frequent occurrence of the letter of firmness and stability, T, communicates the idea of the striking of the wind on objects.

In the "*Andromaque*" of Racine, a line of this character occurs:

> "Pour qui sont ces serpens qui sifflent sur vos têtes,"[2]

in which the sound impressed on the ear has some similarity to the hissing of serpents; and in the "*Poème des Jardins*" of the Abbé Delille, there is the following example:—

> "Soit que sur *l*e *l*imon une rivière *l*ente,
> Dérou*l*e en paix les p*l*is de son onde indo*l*ente;
> Soit qu'a t*r*ave*r*s les *r*ocs un to*rr*ent en cou*rr*oux
> Se b*r*ise avec f*r*acas."[3]

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[1] Op. cit., i. 244. [2] "For whom are those serpents that hiss o'er your heads?"

[3] Which may be translated as follows:—

> "If o'er deep slime a river laves
> In peace the folds of its sluggish waves;
> Or o'er the rocks a torrent breaks
> In wrath obstrep'rous."

In the first two lines, the Liquid L denotes the tranquil flow of the river; whilst in the two last, the letter of roughness and asperity, R, resembles the rushing of the stream like a torrent. The remarks already made will have exhibited the radical difference in the ideas communicated by the sound of those letters, by the common consent of languages. In the German this variety of expression is often had recourse to; and by none more frequently than by the poet Bürger.[1] The English language affords a few specimens, but not as many as might be imagined. Of simple alliteration there are many; some that give delight; others that do violence to the suggestive principle; but there are comparatively few where the words are selected, which by their sound convey to the mind the idea to be communicated. The galloping of horses may be assimilated by a frequent succession of short syllables; slow, laborious progression by the choice of long: but in the onomatopœia in question, the words themselves must consist of such a collocation of one consonant, or of particular consonants, as adds force to the idea communicated by the words collectively. Of this, we have a good example in the lines before cited, in which the repetition of the letter R, in the phonetic words, adds considerable force to the idea intended to be conveyed by the passage—

> "Break his bands of sleep asunder;
> And rouse him like a rattling peal of thunder,"

and in Byron's "Darkness,"

> "Forests were set on fire—but hour by hour
> They fell and faded—and the crackling trunks
> Extinguish'd with a crash—and all was black."[2]

f. Singing.

The singing voice differs from other vocal sounds in consisting of appreciable tones, the intervals of which can be distinguished by the ear, and admit of unison. Under the sense of hearing we endeavoured to show, that the musical ear is an intellectual faculty; and that the ear is only the instrument for attaining a knowledge of sounds, which are subsequently reproduced by the larynx, under the guidance of the intellect. In this respect, therefore, there is a striking resemblance between music and spoken language.

Like the latter, singing admits of considerable difference, as regards intensity, timbre, &c. Voices are sometimes divided into the *grave* and *acute;* the difference between them amounting to about an octave. The former is the voice of the adult male; but he is capable of acute sounds, by assuming the *falsetto*, which M. Savart[3] conceives to be produced in the ventricles of the larynx; M. Bennati in the pharynx; and more recently, Mr. J. Bishop[4] has suggested, that it may arise

[1] Art. Alliteration, and Onomatopœia, in Encyclopédie, par Diderot, D'Alembert, &c., and in Allgemeine Deutsche Real-Encyclopädie für die gebildeten Stände, (Conversations Lexikon), Aufl. 8, Leipz., 1837.

[2] See, on Onomatopœia, by the author, Virginia Literary Museum, p. 65, Charlottesville, 1840.

[3] Magendie's Journal de Physiologie, tom. v., Paris, 1825.

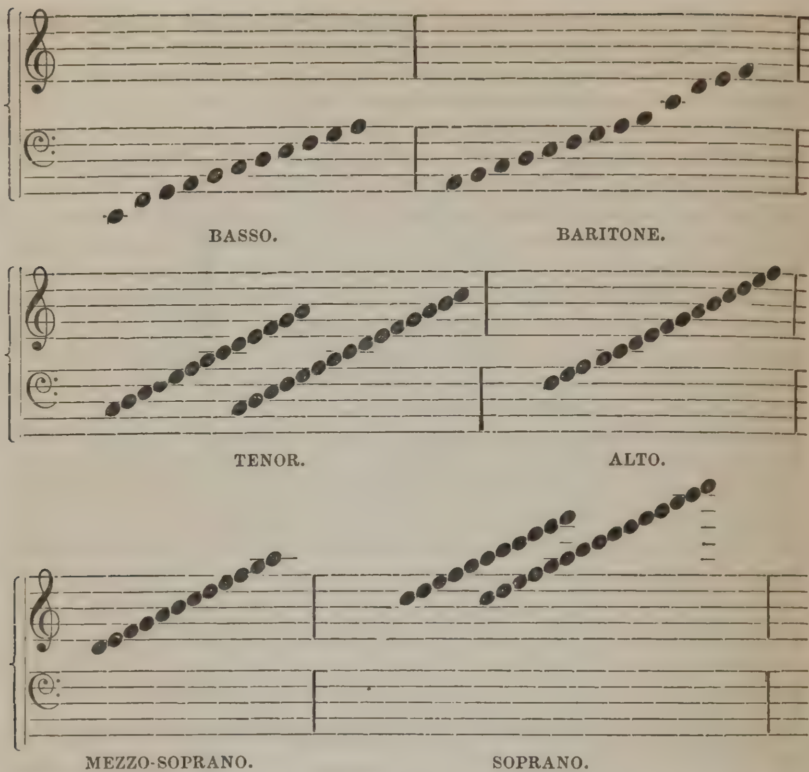
[4] Proceedings of the Royal Society, No. 65, London, 1847. See, also, his Art. Voice, Cyclop. of Anat. and Physiol., iv. 1483, Lond., 1852.

either from the partial closing of the glottis, or from a nodal division of the vocal cords, "the pitch of the sound in the production of this peculiar modification of the voice being such, that the column of air in the vocal tube is of the precise length requisite to vibrate in unison with the larynx." The mode, however, in which the falsetto voice is produced is by no means determined. It has given rise to great diversity of views.[1] The acute voice is that of the grown female, children, and eunuchs. According to M. Pouillet,[2] the gravest sound of the male voice makes 190 vibrations per second; the most acute 678 per second; whilst the female voice makes 572 vibrations for the gravest, and 1606 for the most acute. By adding all the tones of an acute to those of a grave voice, they are found to embrace nearly three octaves; but, according to M. Magendie, it does not appear, that such a compass of voice, in pure and agreeable tones, has ever existed in one individual.[3] On the other hand, M. Biot calculated three octaves and a half to be the extreme range: this, Mr. Bishop[4] says, he knows from experience is too low an estimate. Independently of the falsetto, the compass of the natural voice would seem to rarely exceed two octaves; but in some cases, as in those of Catalani and Malibran, it has extended beyond three. Some singers can descend sixteen tones below, others can rise sixteen above, the medium. The former are called *tenor bass;* the latter *soprano;* but hitherto no example has occurred of a person, who could run through the thirty notes.

The musician establishes certain distinctions in the voice; such as *counter*, *tenor*, *treble*, *bass*, &c. We find it, also, differing considerably in strength, sweetness, flexibility, &c.[5]

The singing voice, according to M. Bennati,[6] is not limited to the larynx,—the pharynx being likewise concerned. The voice, produced in those two different parts, has long been termed *voce di petto*, and *voce di testa.* M. Bennati calls the former *laryngeal notes* or *notes of the first register;* the latter *supra-laryngeal* or *notes of the second register;* and M. Lepelletier designates them *laryngeal* and *pharyngeal* respectively;—comprising, in the dependencies of the pharynx, the tongue, tonsils, and velum palati, by means of which the latter class of sounds is elicited. The *laryngeal voice*, which is always more elevated by an octave in the female than in the male, is most commonly met with. It furnishes the types called, 1. *Soprano;* 2. *Alto* or *Contralto;* 3. *Tenor;* 4. *Bass.* The first two of these belong to the female voice; the last two to the male. They are classed according to their pitch or the middle note of their primary register, as in the subjoined table:—

[1] Müller's Physiology, P. iv. p. 1032, Lond., 1838.
[2] Élémens de Physiologie Expérimentale, tom. iii. 130, Paris, 1832.
[3] Précis Élémentaire, i. 262.
[4] The Lond. and Edinburgh Philosophical Magazine, for October, 1836, p. 272.
[5] Magendie's Journ. de Physiologie, x. 179.
[6] Recherches sur le Mécanisme de la Voix Humaine, Paris, 1832.



The characteristic of these voices, however, is derived less from their pitch than from their timbre or quality. The bass voice generally descends lower than the tenor, and its strength lies in the low notes. The contralto is distinguished for its power in the lower notes of the female voice. Some bass singers can, however, ascend high; and the contralto occasionally ascends as high as the soprano. The baritone is intermediate between the bass and the tenor; the mezzo-soprano intermediate between the alto and soprano.

The *pharyngeal voice* presents only modifications of the above types. It is met with in but few persons in its finest developement. It has usually been supposed to be formed by the superior ligaments of the larynx, or in the ventricles; but these gentlemen esteem it demonstrated, that it is formed at the guttural aperture, circumscribed by the base of the tongue, velum palati, its pillars, and the tonsils. By it is produced the *baritenor*, the *contraltino tenor*, and the *soprano sfogato.* Bennati concludes his memoir on the human voice by remarking,—that not only are the muscles of the larynx inservient to the modulation of the notes of song, but those of the os hyoides, tongue, and the superior, anterior, and posterior part of the vocal tube are called into action, without the simultaneous and properly associated operation of which the degree of modulation requisite for song could not take place.

When the voice is raised in the scale from grave to acute, a corresponding elevation takes place in the larynx towards the base of the

cranium. By placing the finger on the pomum Adami, this motion can be easily felt; at the same time, the thyroid cartilage is drawn up within the os hyoides, and presses on the epiglottis; the small space between the thyroid and cricoid closes; the pharynx is contracted; the velum pendulum depressed and carried forwards; the tonsils approach each other; and the uvula is folded on itself. The reverse of these phenomena takes place during the descent of the voice.[1]

It has been already remarked, that the natural voice or cry is connected with the organization of the larynx. So far as it can be modified into tones independently of the participation of the intellect, a natural singing voice may be said to exist. To repeat, however, any song, requires both ear and intelligence; and, therefore, singing may be said to have originated in social life. It can be employed, as it is in many of our operas, to depict the different intellectual and moral conditions,

"And bid alternate passions fall and rise."

When the air is accompanied by the words, or is articulated, we are capable of expressing, by singing, any of the thoughts or feelings, that can be communicated by ordinary artificial language.

Declamation is a kind of singing, except that the intervals between the tones are not entirely harmonic, and the tones themselves not wholly appreciable. With the ancients—it has been imagined—it differed much less from singing than with the moderns, and probably resembled the *recitative* of the operas. The ingenious work of Dr. James Rush of Philadelphia,[2] may be consulted on all this subject, with great advantage.

b. *Gestures.*

Under this appellation, and that of *muteosis*, are included those functions of expression, that are addressed to the sight and touch. It comprises not only the partial movements of the face, but also those of the upper extremities; besides the innumerable outward signs that characterize the various emotions. In many tribes of animals, the conventional language appears to be almost, if not entirely, confined to the gestures; and even in man—favoured beyond all animals in the facility of communicating his sentiments by the voice—the language of gestures is rich and comprehensive. It is in the gestures of the face chiefly, that he far exceeds other animals. This is, indeed, in him, the great group of organs of expression. In animals, the function is distributed over different parts of the body, the face assuming but little expression, whilst the animal is labouring under any emotion, if we make exception of the brute passion of anger and of one or two others. Hence it is, that, by some naturalists, man has been defined, by way of distinction, "a laughing and crying animal." In animals, almost all the facial expression of internal feeling is confined to the eye and mouth, but, in addition, the attitude of the body is

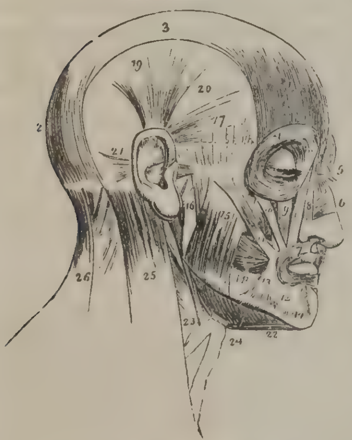
[1] Bishop and Bennati, in op. cit.; and Bushnan, in Orr's Circle of the Sciences, vol. i. p. 132, London, 1854; or the American reprint of his Contribution under the title of The Principles of Animal and Vegetable Physiology, &c., p. 190, Philad., 1854.

[2] Philosophy of the Human Voice, 3d edit., Philad., 1845.

variously modified, and the hair is raised by the panniculus carnosus, as we see on the back of the dog when enraged.

In the human countenance, alone, in the state of society, can the passions be read,—the rest of the body being covered by clothing; and even were it not, the absence of a coat of hair, and of a panniculus carnosus, would enable it to minister but little to expression. The skin of the face is very fine, and on certain parts, as the lips and cheeks, is habitually more or less florid, and admits of considerable and expressive variations in its degree of colour. The union of the different parts composing the face gives occasion to numerous reliefs, which are called *traits* or *features;* and beneath the skin are muscles, capable, by their contraction, of modifying the features in a thousand ways.

Fig. 391.



Muscles of the Head and Face.

1. Frontal portion of occipito-frontalis. 2. Occipital portion. 3. Aponeurosis. 4. Orbicularis palpebrarum, which conceals corrugator supercilii and tensor tarsi. 5. Pyramidalis nasi. 6. Compressor nasi. 7. Orbicularis oris. 8. Levator labii superioris alæque nasi. The figure is placed on nasal portion. 9. Levator labii superioris proprius; the lower part of the levator anguli oris is seen between muscles 10 and 11. 10. Zygomaticus minor. 11. Zygomaticus major. 12. Depressor labii inferioris. 13. Depressor anguli oris. 14. Levator labii inferioris. 15. Superficial portion of masseter. 16. Its deep portion. 17. Attrahens aurem. 18. Buccinator. 19. Attolens aurem. 20. Temporal fascia which covers temporal muscle. 21. Retrahens aurem. 22. Anterior belly of digastricus muscle; the tendon seen passing through its aponeurotic pulley. 23. Stylohyoid muscle pierced by posterior belly of digastricus. 24. Mylo-hyoideus muscle. 25. Upper part of sterno-mastoid. 26. Upper part of trapezius. The muscle between 25 and 26 is the splenius.

To comprehend fully the physiology of the facial expression of the passions, a few observations on the muscles of the human face will be necessary. (Fig. 391.)

The *eyebrow* is greatly concerned in expression; and certain muscles are attached to it for the purpose of moving it. The fasciculus of fibres which descends from the *frontal muscle*, and is attached to the side of the nose, has been esteemed, by some, a separate muscle, and to have a distinct operation. It draws the inner extremity of the eyebrow downwards. When the *orbicularis palpebrarum*, and the last muscle act, there is a heavy lowering expression. If they yield to the action of the frontal muscle, the eyebrow is arched, and there is a cheerful, inquiring expression. If the *corrugator supercilii* acts, there is more or less of mental anguish, or of painful exercise of thought. If it combines with the frontalis, the forehead is furrowed, and there is an upward inflection of the inner extremity of the eyebrow, which indicates more of querulous and weak anxiety. "The arched and polished forehead," says Sir Charles Bell—of whose elegant and accurate *Essays*[1] the author will occasionally avail himself on this branch of the subject—"terminated by the distinct line of the eyebrow, is a table, on which we may see written, in perishable characters, but distinct while they continue, the prevailing cast of thought; and by

[1] Essays on the Anatomy and Philosophy of Expression, 3d edit., Lond., 1844.

the indications here, often the mere animal activity, displayed in the motions of the lower part of the face, has a meaning and a force given to it. Independently of the actions of the muscles, their mere fleshiness gives character to this part of the face. The brow of Hercules wants the elevation and form of intelligence; but there may be observed a fleshy fulness on the forehead, and around the eyes, which conveys an idea of dull brutal strength, with a lowering and gloomy expression, which accords with the description in the *Iliad*."

Sir Charles separates the *orbicularis palpebrarum* into two muscles;—the outer, fleshy, circular band, which runs round the margin of the orbit; and the lesser band of pale fibres, which lies upon the eyelids. The latter is employed in the act of closing the eyelids, but the former is only drawn into action in combination with the other muscles of the face in expressing passion, or in some convulsive excitement of the organ. In laughing and crying, the outer and more powerful muscle is in action, gathering up the skin about the eye, and forcing back the eyeball itself. In drunkenness, the power of volition over this muscle is diminished; and there is an attempt to raise the upper eyelid by a forcible elevation of the eyebrow.

The *muscles of the nostrils* are; 1st, *levator labii superioris alæque nasi*, which, as its name imports, raises the upper lip and nostril; 2dly, *compressor nasi*, a set of fibres which compress the nostril; and 3dly, *depressor alæ nasi*, which lies under *orbicularis oris*, and whose function is indicated by its name. The three muscles serve to expand and contract the opening or canal of the nostril, moving in consent with the muscles of respiration, and thus the inflation of the nostrils indicates general excitement, and animal activity.

The muscles of the lips are; 1st, *levator labii proprius*, which raises the upper lip; 2dly, *levator anguli oris*, which raises the angle of the mouth; and 3dly, the *zygomatic muscle*, which is inserted into the angle of the mouth. Sometimes an additional muscle of the name exists:—*zygomaticus minor*. These last muscles raise the upper lip and angle of the mouth, so as to expose the canine teeth. If they be in action contrary to the orbicularis oris, there is a painful and bitter expression; but if they be influenced along with the orbicularis oris, and orbicularis palpebrarum,—if the former of these muscles be relaxed, and the latter contracted,—there is a fulness of the upper part of the face, and a cheerful, smiling expression of countenance. The *orbicularis oris* closes the mouth; and, when allowed to act fully, purses the lips. The *nasalis labii superioris* draws down the septum of the nose. The *triangularis oris* or *depressor labiorum* indicates, by its name, its function. The *quadratus menti* is a depressor of the lower lip. The *levatores menti*, by their action, draw up the chin, and project the lower lip; and the *buccinator* is chiefly for turning the alimentary bolus in the mouth; and, in broad laughter, retracts the lips. The orbicularis muscle is affected in the various emotions of the mind; trembling and relaxing in both grief and joy; it relaxes pleasantly in smiling.

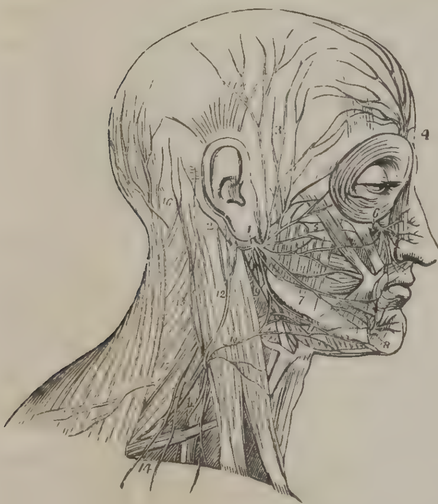
The union of these various muscles at the angle of the mouth produces the fleshy prominence noticed in those who have thin faces; and who are, at the same time, muscular. When the cheeks are fat and full, the action of these muscles produces the dimpled cheek. The

angle of the mouth is full of expression, according as the orbicularis, or the superior or inferior muscles inserted into it have the preponderance.

Lastly; the *temporal* is a strong muscle, which raises the lower jaw. It is assisted by the *masseter*, a deep-seated muscle, which lies on the outside of the lower jaw; arises from the jugum, and is inserted into the angle of the jaw.

Two different nerves are distributed to these muscles,—the fifth pair, and portio dura or facial of the seventh; the latter of which, according to the experiments of Sir Charles Bell, is concerned in the instinctive movements of expression; and comparative anatomy exhibits, that the number and intricacy of these nerves vary in proportion to the animal's power of expression. The nerves of the face and neck of thé monkey are numerous, and have frequent connexions; but on cutting the seventh pair or *respiratory nerve of the face* of Sir Charles Bell's system, the features are found to be no longer influenced by the passions. Yet the skin continues sensible, and the muscles of the jaws and tongue are capable of the actions of chewing and swallowing. If the respiratory nerve of one side be cut, the expression of that side is destroyed; whilst the chattering, grinning, and other movements of expression continue on the other. In a dog, too, if the respiratory nerve of the face be cut, he will fight as bitterly, but with no retraction of his lips, sparkling of the eye, or drawing back of the ears. The face is inanimate, although the muscles of the face and jaws, so far as they are liable to be influenced through other nerves, continue their office. The game-cock, in the position of fighting, spreads a ruff of feathers around his head. The position of his head and the raised feathers are the expressions of hostile excitement; but on the division of the respiratory nerve, the feathers are no longer raised, although the pugnacious disposition continues. It has been found, moreover, that if the galvanic influence be passed from one divided extremity of the

Fig. 392.

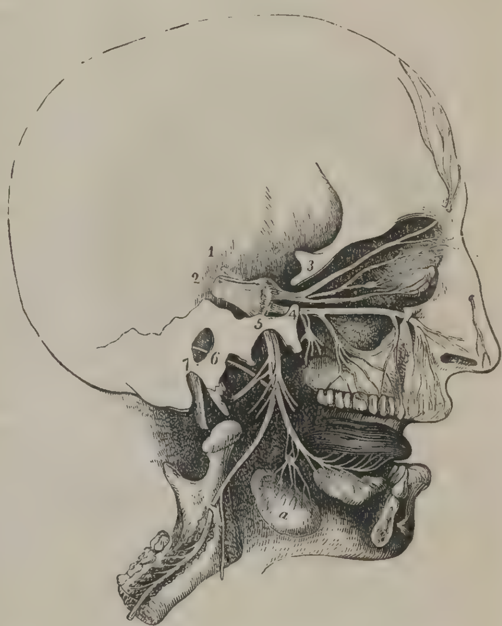


Distribution of Facial Nerve.

1. Facial nerve, escaping from stylo-mastoid foramen, and crossing ramus of lower jaw; the parotid gland has been removed in order to see the nerve more distinctly. 2. Posterior auricular branch; the digastric and stylo-mastoid filaments are seen near origin of this branch. 3. Temporal branches, communicating with (4) branches of frontal nerve. 5. Facial branches communicating with (6) infra-orbital nerve. 7. Facial branches, communicating with (8) mental nerve. 9. Cervico-facial branches communicating with (10) superficialis colli nerve, and forming a plexus (11) over submaxillary gland. Distribution of branches of the facial in a radiated direction over side of face constitutes the *pes anserinus*. 12. Auricularis magnus nerve, one of ascending branches of cervical plexus. 13. Occipitalis minor, ascending along posterior border of sterno-mastoid muscle. 14. Superficial and deep descending branches of cervical plexus. 15. Spinal accessory nerve, giving off a branch to external surface of trapezius muscle. 16. Occipitalis major nerve, posterior branch of second cervical nerve.

respiratory nerve to the other, the facial expression returns; and, in certain cases of incomplete hemiplegia, in which the movements of expression of the face were alone rendered impracticable, the disease was found to have implicated only the respiratory or facial nerve. The views of Sir Charles Bell regarding the connexion alleged by him to subsist between the seventh pair and the associated movements of respiration have, however, been contradicted by the experiments of Mr. Mayo,[1] and his inferences regarding the fifth pair as being jointly a nerve of sensation and of voluntary motion have been considered to require qualification. By dividing the portio dura of the seventh pair in the ass, and on both sides instead of one, as done by Sir Charles Bell, Mr. Mayo found, that the nerve presides over simple voluntary motion only; and by a similar division of the second and third branches of the fifth, at their points of convergence, he showed, that the lips were deprived of sensation, not of motion. "No doubt, I believe," says Mr. Mayo, "is now entertained, that the inference which I drew from these experiments is correct; namely, that the portio dura of the seventh pair is a simple voluntary nerve, and that the *facial branches* of the fifth are exclusively sentient nerves." In the prosecution of his inquiries, Mr. Mayo observed, that the masseter muscle, temporal, pterygoids, and circumflexus palati receive no branches from any nerve except the fifth, and yet that they receive no twigs from the ganglionic portion of the nerve; and thence he concludes, that almost all the branches of the large or ganglionic portion of the fifth pair are nerves of sensation, whilst those of the small fasciculus or *ganglionless* portion are nerves of motion. This smaller portion of the fifth pair issues from the peduncles of the brain; constitutes a gangliform plexus with the inferior maxillary only; presents the common aspect of most nerves of the body, and is distri-

Fig. 393.



Plan of the Branches of the Fifth Nerve, modified from a sketch by Sir C. Bell.

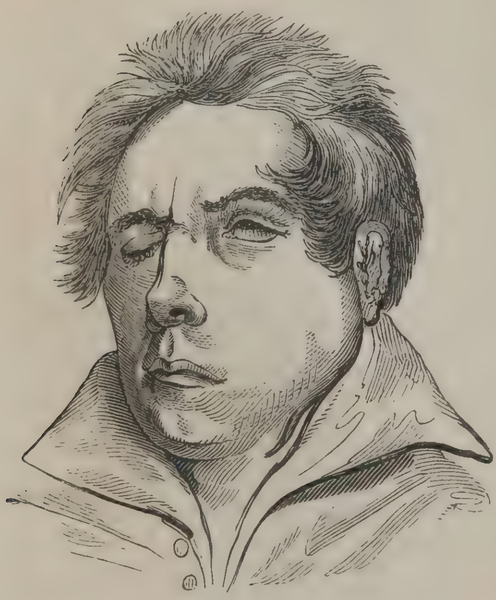
a. Submaxillary gland, with the submaxillary ganglion above it. 1. Small root of the fifth nerve, which joins the lower maxillary division. 2. Larger root, with the Gasserian ganglion. 3. Ophthalmic nerve. 4. Upper maxillary nerve. 5. Lower maxillary nerve. 6. Chorda tympani. 7. Facial nerve.

[1] Outlines of Human Physiology, 4th edit., p. 254, London, 1837.

buted to the chief muscles concerned in the process of mastication. Hence it was termed by Bellingeri[1] *nervus masticatorius;* and by Sir Charles Bell, long afterwards, *motor* or *manducatory portion of the fifth pair.* To this smaller fasciculus of the fifth, twigs from the ganglionic portion of the nerve are distributed. The ganglionless portion, and portio dura of the seventh, Mr. Mayo conceives to be voluntary nerves to parts, which receive sentient nerves from the larger or ganglionic portion of the fifth. The facial nerve, however, after it has passed through the parotid gland, becomes sensory also, owing to its having received a twig from the fifth pair.

Pathology affords numerous examples of injury done to the facial nerve. In some of these, the nerve itself may be in a morbid condition in a portion of its course; in others, the part of the encephalon, whence the nerve originates, may be the seat of the lesion. The prognosis will, of course, vary according to the seat; but, as a general rule, paralysis of the facial nerve is not of great moment. The author has seen several cases of partial paralysis of this kind; some of which have wholly disappeared; but in others the loss of power appears to be permanent. In a case, which presented itself to him in the Baltimore Infirmary, the mischief was probably seated near the origin of the nerve, as it resulted from serious injury to the head. A carriage-horse, belonging to a friend, by exerting considerable power, forced its head through an aperture in the partition of the stall, and was unable to withdraw it, in consequence of the under jaw catching the sides of the aperture. During the efforts to extract it, so much pressure was made upon the portio dura of one side, that the animal lost all power of expression in the corresponding side of the head; the soft parts about the mouth dropped, and the ear no longer associated with that of the opposite side in expression; yet the movements of mastication and deglutition were scarcely affected. This state of paralysis continued for a few days, and gradually disappeared. Fig. 394 represents a case of paralysis of this nerve, produced

Fig. 394.



Paralysis of the Facial Nerve.

[1] Dissert. Inaugur., Turin., 1823; cited in Edinb. Med. and Surg. Journ., July, 1834.

by the pressure of a tumour beneath the ear; the orbicularis palpebrarum was paralysed so that the patient was unable to close his eyelids.

Independently of the various muscular actions which modify the expression of the human countenance, there are certain others that mark the different mental emotions. The skin varies in colour, becoming pale or suffused, and frequently alternating rapidly between these two conditions. The changes are more especially witnessed on the forehead, cheeks, and lips; and arise from an augmented or diminished flow of blood into the capillaries of the part, under the influence of the existing emotion. Under such circumstances, the eye may participate in the suffusion. The skin may, also, vary in its degree of moisture or heat; it may be dry, or bathed in perspiration; and the perspiration may be warm or cold;—the two conditions occasionally alternating. Particular parts of the face, again, are more susceptible of this "sweat of expression," as it has been termed,—the forehead and temples for example. The heat of the head is also occasionally modified; a sudden glow is felt in the countenance; and the expression is sometimes evident to a second person.

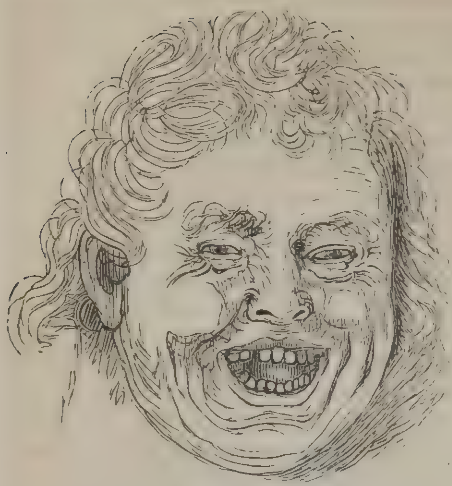
The expression of the human eye, connected with the action of the oblique muscles, has been referred to under Vision. It was there asserted, that in insensibility, the organ, it has been presumed, is given up to the action of the oblique muscles, and is drawn up under the upper eyelid. The eye itself is, however, capable of various expressions, depending upon varied positions of its tutamina; and especially of the secretion from its mucous covering—the conjunctiva,—and from the lachrymal gland; so that it may be *swimming*, or the tears may flow over the cheeks and constitute *weeping*.

In addition to these, which may be esteemed sources of expression in the human countenance, may be added the action of *osculation* or *kissing;* which, wherever practiced, is employed as an expression of love and friendship;—confined with us to those of the female sex, or of opposite sexes; but, in some countries, employed as an expression of regard between males also.

It is impracticable to describe all the facial expressions—*Prosoposis*, as they have been collectively termed—of which the human countenance is susceptible. They are commonly classed under two heads; the *exhilarating*, in which the face is flushed, and the countenance expanded;—the muscles being contracted from within to without; and the *depressing*, in which, on the contrary, the face is pale, and the features are drawn inwards and sunken.

Let us inquire into the physiology of a few of these expressions; beginning with the play of the features in broad *laughter*, (Fig. 395,) as being, perhaps, the most easy of explanation. In laughing, it is in vain that we endeavour to confine the lips; a complete relaxation of the orbicularis oris gives uncontrolled power to the opponent muscles inserted into the angles of the mouth and upper lip. Hence, the lateral retraction of the angles of the mouth; the elevation of the upper lip disclosing the teeth; the peculiar elevation of the nostrils without their being expanded, and the dimple of the cheek where the acting muscles congregate: hence, also, the fulness of the cheeks, rising so as to conceal the eye, and throw wrinkles about the lower eyelids

Fig. 395.



Broad Laughter.

and temples. In this expression, the whole of the movable features are raised upwards. The orbicularis palpebrarum does not partake of the relaxation of the orbicularis oris. It is excited, so as to contract the eyelids, and sink the eye, whilst the struggle of a voluntary effort of the muscles to open the eyelids, and raise the eyebrow, gives a twinkle to the eye, and a peculiar obliquity to the eyebrow, the outer part of which is most elevated. At the same time, the individual holds his sides, to control the contractions of the muscles of the ribs. The diaphragm is violently agitated. The same influence spreads to the throat, and the sound of laughter is as distinct as the signs in the face.

In this movement of expression we have an instance of the associated action of different parts, which are considered to be under the influence of the respiratory system of nerves of Sir Charles Bell. The facial expression is under the direction of the portio dura or respiratory nerve of the face.

Fig. 396.

Faun Weeping.

In the face of a faun, (Fig. 396,) sketched by Sir Charles Bell, we have the expression of *weeping* from pain. In the violence of weeping, accompanied with lamentation and outcry, the face is flushed or suffused from stagnation of blood in the vessels. The muscles of respiration are affected from the commencement, and the return of blood from the head is somewhat impeded. The muscles of the cheeks are in movement. Those that

depress the angles of the mouth are powerfully contracted, and the orbicularis oris is not relaxed, but drawn open by the predominant action of its opponents. A convulsive movement in the muscles about the eyes attends; the eyebrow is drawn down; the eyes are compressed by the eyelids; the cheek is raised; the nostril drawn out, and the mouth stretched laterally. In weeping, also, unless the convulsive movement of the muscles is very strong, the expression of grief affects that part of the eyebrows next the nose. It is turned up with a peevish expression, which corresponds with the depression of the corners of the mouth. This depression gives an air of despondency and languor to the countenance, when accompanied by general relaxation of the muscles. When the corrugator co-operates, there is mingled in the expression something of mental energy, moroseness, or pain. If the frontal muscle unites its action, an acute turn upwards is given to the inner part of the eyebrow, very different from the effect of the general action of the frontal muscle, and characteristic of anguish, debilitating pain, or discontent, according to the prevailing cast of the rest of the countenance. The depression, however, of the angle of the mouth, that indicates languor and despondency, must be slight; as the depressor anguli oris cannot act forcibly, without the action of the superbus participating—a muscle, which quickly produces a revolution in the expression, and makes the under lip pout contemptuously.

The expression at the angles of the mouth demands the careful study of the painter; the most opposite characters being communicated to the countenance by their elevation or depression. When Peter of Cortona was engaged on a picture of the iron age for the royal palace of Pitti, Ferdinand II., who often visited him, and witnessed the progress of the piece, was particularly struck with the exact representation of a child in the act of crying. "Has your majesty," said the painter, "a mind to see how easy it is to make this very child laugh?" The king assented: and the artist, by merely elevating the corner of the lips and inner extremity of the eyebrows, made the child, which at first seemed breaking its heart with weeping, seem equally in danger of bursting its sides with immoderate laughter, after which, with the same ease, he restored to the figure its proper expression of sorrow.[1]

It is at the angle of the mouth and the inner extremity of the eyebrow that the expression which is peculiarly human is situate. These are the most movable parts of the face. On them the muscles are concentrated, and it is upon their changes that expression is acknowledged chiefly to depend. All the parts, however, of an impassioned countenance are in accordance with each other. When the angles of the mouth are depressed in grief, the eyebrows are not elevated at the outer angles as in laughter. When a smile plays around the mouth, or when the cheek is elevated in laughter, the eyebrows are not ruffled as in grief. In real emotion, these opposite actions cannot be combined; and, when united by the mimic, the expression is farcical and ridiculous.

Dr. Wollaston[2] has shown, that the same pair of eyes may appear to direct themselves either to or from the spectator, by the addition of

[1] Good's Book of Nature, iii. 291, Lond., 1834.

[2] Philosophical Transactions, for 1824, p. 247; see, also, Letters on Natural Magic, by Sir D. Brewster, Amer. edit., p. 115, New York, 1832.

other features in which the position of the face is changed. The nose principally produces the change of direction, as it is more subject to change of perspective than any other feature; and Dr. Wollaston has shown, that even a small portion of the nose will carry the eyes along with it. He obtained four exact copies of the same pair of eyes looking at the spectator, by transferring them upon copper from a steel plate, and having added to each of two pairs of them a nose—in one case directed to the right, and in the other to the left, and to each of the other two pairs a very small portion of the upper part of the nose—all the four pairs of eyes lost their front direction, and looked to the right or to the left, according to the direction of the nose, or of the portion of it that was added. But the effect thus produced is not limited to the mere change in the direction of the eyes; for a total difference of character may be given to the same eyes by a due representation of the other features. A lost look of devout abstraction in an uplifted countenance may be exchanged for an appearance of inquisitive archness in the leer of a younger face turned downwards and obliquely towards the opposite side. This, however, as Sir David Brewster has remarked, is not perhaps an exact expression of the fact. The new character, which is said to be given to the eyes, is given only to them in combination with the new features; or what is probably more correct, the inquisitive archness is in the other features, and the eye does not belie it. Sir David adds, that Dr. Wollaston has not noticed the converse of these illusions, in which a change of direction is given to fixed features by a change in the direction of the eyes. This effect is seen in some magic lantern sliders, where a pair of eyes is made to move in the head of a figure, which invariably follows the motion of the eyeballs.

In *bodily pain*, the jaws are pressed together, and there is grinding of the teeth; the lips are drawn laterally, so as to expose the teeth and gums; the nostrils are distended to the utmost, and at the same time drawn up; the eyes are largely uncovered, and the eyebrows elevated; the face is turgid with blood, and the veins of the temple and forehead are distended; the breath being suspended, and the descent of the blood from the head impeded.

In *anguish*, conjoined with *bodily suffering*, the jaw falls, the tongue is seen; and, in place of the lateral retraction of the lips, the lower lip falls; the eyebrows are knit, whilst their inner extremities are elevated; the pupils of the eyes are in part concealed by the upper eyelids, and the nostrils are agitated. Agony of mind is here added to the bodily suffering, which is particularly indicated by the change in the eyebrow, and forehead.

In *rage*, the features are unsteady; the eyeballs are largely seen, roll, and are inflamed. The forehead is alternately knit and raised in furrows by the motion of the eyebrows; and the nostrils are inflated to the utmost; the lips are swelled, and, being drawn, open the corners of the mouth. The action of the muscles is strongly marked. The whole countenance is at times pale; at others, inflated, dark and almost livid; the words are passed forcibly through the fixed teeth, and the hair is on end.

Fear has different degrees. Mere *bodily fear* resembles the mean anticipation of pain. The eyeball is largely uncovered; the eyes are

staring, and the eyebrows elevated to the utmost stretch. To these are added a spasmodic affection of the diaphragm and muscles of the chest, which affects the breathing, and produces a gasping in the throat, with an inflation of the nostrils, convulsive opening of the mouth, and dropping of the jaw;—the lips nearly concealing the teeth, yet allowing the tongue to be seen, and the space between the nostril and lip being full. There is a hollowness and convulsive motion of the cheeks, and a trembling of the lips and muscles on the sides of the neck. The lungs are kept distended; and the breathing is short and rapid. The surface is pale from the recession of blood; and the hair is lifted up by the creeping of the skin. In fear, where the apprehended danger is more remote, but is approaching, the person trembles and looks pale; a cold sweat is on the face; the scream of fear is heard; the eyes start forward; the lips are drawn wide; the hands are clenched, and the expression becomes more strictly animal, and indicative of such fear as is common to brutes.

In *terror* or that kind of fear in which the mind participates more there is a more varying depression in the features, and an action of those muscles, which are peculiar to man, and seem to indicate his superior intelligence and mental feeling. The eye is bewildered; the inner extremity of the eyebrows is turned up, and strongly knit by the action of the corrugator and orbicular muscles; and distracting thoughts, anxiety and alarm are strongly indicated by this expression, which does not belong to animals. The cheek is slightly elevated, and all the muscles, that concentrate about the mouth, are in action.

In *admiration*, the forehead is expanded and unruffled; the eyebrow gently raised; the eyelid lifted so as to expose the coloured circle of the eye, whilst the lower part of the face is relaxed into a gentle smile. The mouth is open; the jaw is a little fallen; and, by the relaxation of the lower lip, we just perceive the edge of the lower teeth and the tongue.

In *joy*, the eyebrow is raised moderately, but without any angularity; the forehead is smooth; the eye full, lively and sparkling; the nostril moderately inflated, and a smile is on the lips.

This subject is, however, interminable. Enough has been stated to exhibit the anatomy of the varying characters of facial expression. It will be found beautifully treated and illustrated in the work of Sir Charles Bell, to which reference has been made.

From all that has been said, it is evident, that the countenance is a good general index of the existing state of the feelings; but farther than this it cannot be depended upon. Yet, in all ages, it has been regarded as the index of individual character. Allusion has been made to the estimate of personal character from the shape of the head, as described by the older poets. Similar indications were conceived to be deducible from the form of the face, expression of the eyes, &c. Thus Shakspeare:—

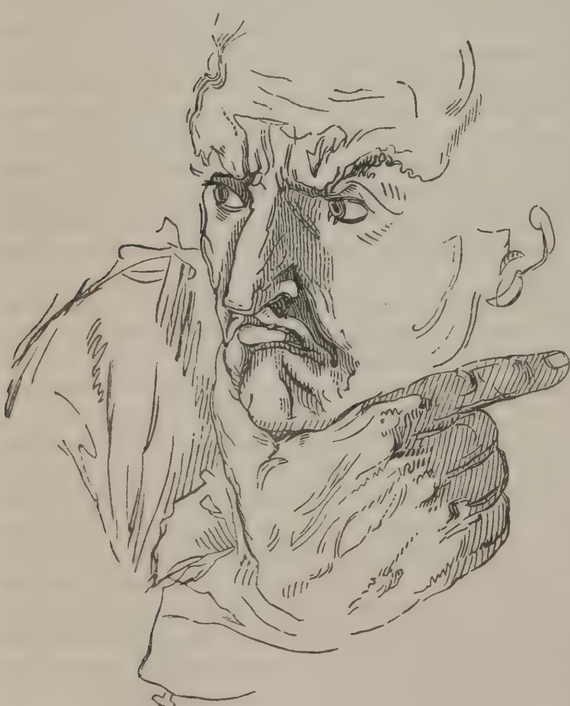
> *Cleopat.* "Bear'st thou her face in mind? is't long or round?
> *Messeng.* Round, even to faultiness.
> *Cleopat.* For the most part, too,
> They are foolish that are so. Her hair, what colour?
> *Messeng.* Brown, madam, and her forehead
> As low as she would wish it."
>
> ANTONY AND CLEOPATRA, iii. 3.

And again:—

> "Which is the villain? Let me see his eyes,
> That when I note another man like him,
> I may avoid him." MUCH ADO ABOUT NOTHING.

John Baptist Porta[1] and Lavater[2] have endeavoured to establish a "science," by which we can be instructed, how to discover the secret dispositions of the head and heart from the examination of particular features. The latter enthusiast, in particular, appears to have carried his notions to the most chimerical extent. "No study," he remarks, "excepting mathematics, more justly deserves to be termed a *science* than *physiognomy*. It is a department of physics including theology and belles lettres, and in the same manner with these sciences may be reduced to rule. It may acquire a fixed and appropriate character. It may be communicated and taught." In another place, he remarks, that no person can make a good physiognomist unless he is a well-proportioned and handsome man;[3] yet he himself was by no means highly favoured in these respects; and it is difficult to say, according to his own theory, how he obtained such progress in the "*science*"!

Fig. 397.



Physiognomy of Melancholy.

There is one case, and perhaps, one only, in which physiognomy can aid us in the appreciation of character. It has been remarked, that the facial expression may accurately depict the existing emotion. If, therefore, any passion be frequently experienced, or become habitual, its character may remain impressed upon the countenance, and admit of an opinion being formed of the individual. No one, who has seen the melancholy mad, can mistake the piteous expression produced by brooding over the corroding idea that en-

[1] La Physiognomie Humaine de Jean Baptiste Porta, Rouen, 1655.
[2] Works, from the French, by G. Grenville, Esq., Lond.; or Précis Analytique et Raisonné du Système de Lavater, par N. J. Ottin, Bruxelles, 1834.
[3] Good's Book of Nature, iii. 309, Lond., 1834.

grosses him. In the sketch (Fig. 397), from Sir Charles Bell,[1] we have the testy, peevish countenance, bred of melancholy; of one who is incapable of receiving satisfaction from whatever source it may be offered, and who "cannot endure any man to look steadily upon him, even to speak to him, or laugh, or jest, or be familiar, or hem, or point, without thinking himself contemned, insulted, or neglected." Such a countenance no one can misapprehend. In lesser degrees, particular features are found bearing, or seeming to bear, the impress of particular emotions; and, accordingly, we are in the daily habit of forming opinions at first sight, both of the intellectual and moral characteristics of individuals, by the expression of the countenance. Of course, we are frequently led into error; inasmuch as habitual feelings alone are indicated by the physiognomy, whilst the natural disposition may be of an opposite character. The fallaciousness of this mode of judging of mankind has been proverbial in all times. Whenever we attempt to decide upon a man's intellectual powers by the rules laid down by Lavater we are constantly deceived; and, in this respect, he has himself evidently fallen into gross errors.

What may be, not inappropriately, styled "*medical physiognomy*," or the changes of features indicative of, and peculiar to, different diseases and stages of disease, is a subject of moment, and has not met with sufficient attention. In diseases of infancy in particular, the appearance of the countenance often materially aids us in discriminating their seat. There is a marked difference between the facial expression of one labouring under violent pain in the head, and of one suffering from excruciating pain in the abdomen, even in the adult. Less degrees of pain are, of course, disregarded; and it is only in severe cases that physiognomy can be inservient to diagnosis; but in the infant, which readily gives expression to pain or uneasiness, the countenance is an excellent medium of discrimination, and frequently indicates, at the first glance, the seat of the derangement. The character, too, of the countenance, in serious disease, as to anxiety, convulsion, &c., is often a subject of watchful interest with the physician.[2] Mute expression is not, however, restricted to the face, although, as already remarked, in civilized man, whose nakedness is covered, we are shut out from the observation of many acts of this nature. During emotion, the skin covering the body may participate with that of the face in its changes from pale to red; and it may be warm or cold; dry or bathed in perspiration; or, during particular depressing passions, may creep and exhibit the rough character of the *cutis anserina* or *goose skin*. Under special emotions, the erectile tissues of the organs of generation, and of the nipple in the female, experience turgescence. All these changes are more or less concealed from view. We are, therefore, more familiar with the sight of phenomena of expression, that affect the whole body, as regards its different attitudes and modes of progression. How tremulous and vacillating is the attitude of one labouring under fear; and how different the port of the meek and lowly from that of the proud

[1] Anat. of Expression, edit. cit.

[2] See, on special medical physiognomy, M. Jadelot, cited by M. de Salle, in Traité des Maladies des Enfans de Michael Underwood, &c., p. 36 et seq.; and in the author's Commentaries on Diseases of the Stomach and Bowels, p. vii., Lond., 1824.

and haughty! In walking, we observe a similar difference; and can frequently surmise the passion, whether exhilarating or depressing, under which a person, at a distance, may be labouring, from the character of his progression.

> "You may sometimes trace
> A feeling in each footstep, as disclosed
> By Sallust, in his Catiline, who, chased
> By all the demons of all passions, showed
> Their work even by the way in which he trode."
> BYRON'S "*Don Juan*."

Again, on the communication of sudden tidings of joy, we feel a desire to leap up, and give way to the most wild and irregular motions; whilst the shrinking within ourselves, as it were, and the involuntary shudder, sufficiently mark the reception of a tale of horror.

Properly speaking, the subject of cranioscopy belongs to the function of expression, but it has already been considered under another head.

Many of the partial movements constitute an important part of the language of expression, especially with the savage, and with those unfortunates who are debarred the advantages of spoken language. In almost all nations, the motions of the head on the vertebral column are used as signs of affirmation or negation;—the former being indicated by a sudden and short forward flexion of the head on the column; the latter, by a rapid and short rotation on the axis or vertebra dentata. The shoulders are shrugged in testimony of impatience, contempt, &c. The upper extremities are extensively employed as a part of conventional language, and were probably used for this purpose before speech was invented. The open and the closed hands communicate different impressions to the observer; the pointed finger directs attention to the object we desire to indicate, &c. When persons are at such a distance from each other, that the voice cannot be heard, this is the only language they can have recourse to; and the various important inventions, by which we communicate our feelings to a distance, such as writing and telegraphing, belong to this variety of language. For the deaf and dumb, our ordinary spoken language is translated into gestures, by which a conversation can be held, sufficient for all useful purposes; whilst the deaf, dumb, and blind are mainly restricted to those gestures that are conveyed through their sense of touch.

Each acquired gesture is, like each acquired movement of the glottis, an evidence of the possession of intellect. The infant and the idiot have them not, because unable to appreciate their utility. The gestures resemble the spoken language in this and many other respects. The eye sees the gesture, to which the intellect attaches an idea as it does to the sound conveyed by the organ of hearing; and the will reproduces the gesture, in the same manner as it reproduces the sound heard. The lower extremities are, also, slightly concerned in the function of expression. They are agitated when impatient, and incessantly changing their position. The foot is stamped upon the ground in anger; and, like the upper extremity, is employed to convey to the object that has aroused the emotion the most unequivocal evidences of expression. Occasionally, the lower extremity is used as a part of

conventional language, as when we tread upon the toes to arouse attention, or to convey insult. Nor are the internal organs foreign to the function of expression. The respiratory movements are affected,—the number of respirations being accelerated or retarded, or manifesting themselves under the different modifications of *sighing*, *yawning*, *laughing*, and *sobbing*. The heart, too, throbs at times to such an extent, that its action is perceptible externally; or, it may be retarded or hurried in its pulsations,—from a state of syncope or fainting to that of the most violent palpitation.

Lastly: the excretions, certain of them especially, are greatly implicated in many of these moral changes. That of the tears is a well-known and characteristic expression—of grief more especially, but occasionally of joy. The mind, however, may be so possessed by the emotion, that the ordinary power over the sphincter muscles may be more or less destroyed, and the contents of the rectum be spontaneously evacuated. The action of the stomach is, at times, inverted; and, at others, the peristaltic action is augmented. Who has not felt, whilst labouring under anxiety or dread, the constant desire not only to evacuate the fæces, but also the urinary secretion!

It is obvious, from this detail, that there is scarcely a function, which does not *express* some participation, when the mind is engaged in deep emotion; and that it would be vain to attempt to depict the various forms under which these manifestations may occur. What has been said will suffice to attract attention to the subject, which is not devoid of interest to the anthropologist.

In conclusion, we may refer to the question that has often been agitated, whether these rapid and violent movements, that characterize the expression of emotions, be *instinctive* or *natural* signs of the passion existing in the mind; or whether they be not voluntary muscular exertions, called for by the stress of the case, and constituting the means of resistance, or belonging simply to the outward manifestation of the inward emotion. The supporters of the latter view contend, that the various changes of facial expression or of gesture, which accompany the different mental emotions and indicate their character, are, in all cases, the effect of habit, or are suddenly excited to accomplish some beneficial purpose. It is difficult, however, to regard the different concomitants of the passion as separate from it. Without them, the expression is incomplete; and, moreover, we observe the different gestures similarly developed in all the various races of mankind, when affected with the same mental contention. We must, consequently, regard the expressions as constituting a natural language, in which each has its appropriate sign; and this view is confirmed by the fact, that there are certain muscles of the face, which seem, in our existing state of knowledge, to be exclusively destined for expression;—those about the eyebrows and angles of the mouth for example. When the triangularis muscle and levator menti combine action, an expression is produced, which is peculiar to man; the angle of the mouth is drawn down, and the lip arched and elevated; hence the most contemptuous and proud expression.

A question of a different character has, however, been mixed up

with this:—whether the infant be capable instinctively or naturally of comprehending the difference between the facial expressions of kindness or of frowns; some believing, that smiles are merely considered by it to be expressions of kindness, because accompanied by endearments,—and frowns to be proofs of displeasure, because followed by punishment. It is certain, however, that the infant interprets the countenance long before it can trace such sequences in its mind; but this does not remove the difficulty. The face of one, whom it has not been accustomed to see, will, at a very early period, impress it unfavourably, although the countenance may be unusually prepossessing; and the alteration of the ordinary expression of the maternal countenance may be attended with similar results. It is difficult, indeed, to comprehend how the child should be capable of discriminating between the smile and frown, when first presented to it. That organs may be associated in the expression of any encephalic act is intelligible; but that an act of judgment can be executed naturally or instinctively appears inexplicable. Sir Charles Bell,[1] who maintains the doctrine of the instinctive character of the expression of human passions, rejects the notion of instinctive expression in the face of the quadruped, contending that, even in the passion of rage, which is the most strongly marked of all the changes that occur in the features, are merely motions accessory to the great objects of opposition, resistance, and defence. "In carnivorous animals," he remarks, "the eyeball is terrible, and the retraction of the flesh of the lips indicates the most savage fury. But the first is merely the excited attention of the animal, and the other a preparatory exposure of the canine teeth." It appears to be a sufficient answer to this view, that no such expression is ever witnessed in other cases of excited attention, or in the simple exposure of the canine teeth, when the animal is devouring its food; unless, indeed, the repast be made during the existence of the passion.

On a former occasion, it was remarked, that the encephalon is exclusively concerned in the production of the different passions, and that the parts to which they are usually referred, attract our attention to them, principally in consequence of the sensation which accompanies them being there chiefly experienced. The same may be said of the different gestures that accompany the various emotions. They are dependent upon the influence exerted by the function of sensibility on the other functions. Gall,[2] in his system, has feebly attempted to show, that each gesture has a reference to the encephalic situation of the organ concerned in the production of the emotion of which it is a concomitant. The idea was suggested to him, he asserts, by the fact, observed by him a thousand times, that in fractures of the skull, the hand, (naturally we should think,) was carried mechanically to the seat of the fracture. He farther remarks, that the organs of the memory of words and of meditation are seated in the forehead; and that the hand is carried thither, whenever we are engaged in deep study;—that the organ of religious instinct corresponds to the vertex; and hence, in the act of prayer, all the gestures are directed towards that part of

[1] Anat. of Expression, edit. cit.
[2] Sur les Fonctions du Cerveau, v. 436, Paris, 1825.

the body. Like every professed systematist, Gall is here pushing his principles *ad absurdum.* They are, indeed, controverted by facts. The hand is usually carried, not to the part of the encephalon in which any passion is effected, but to the part of the body in which its more prominent effects are perceptible,—as to the region of the stomach or heart; and frequently the gesture is referable to the determinate action, which must be regarded as a necessary effect of the passion.

Finally, *sculpture* and *painting* belong properly to the varieties of expression; but they are topics that do not admit of elucidation by physiology.

Here terminates the history of the animal functions, which have the common character of being periodically suspended by sleep. By many physiologists, this function has, therefore, been examined in this place; but as the nutritive and generative functions are, likewise, greatly influenced by sleep, we shall follow the example of M. Magendie,[1] and defer its study until those functions have been inquired into.

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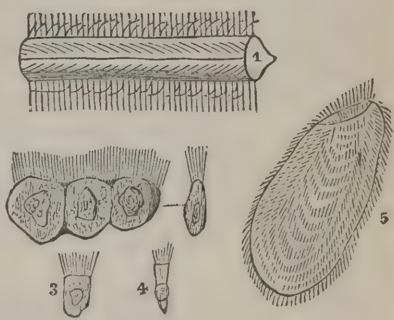
6. CILIARY MOTION.

Although not an animal function, it may be convenient to allude, in this place, to the phenomena of *vibratory* or *ciliary motion*, which, in recent times, have received the attention of observers. These terms have been employed to express the appearance produced by cilia,—a peculiar sort of moving bodies resembling small hairs, which are visible by the aid of the microscope, on parts that are covered with ciliary or vibratory epithelium.[2]

Fig. 398.



Cilia.

1. Portion of a bar of the gill of the *Mytilis edulis*, showing cilia at rest and in motion. 2. Ciliated epithelium particles from frog's mouth. 3. Ciliated epithelium particle from inner surface of human membrana tympani. 4. Ditto, ditto: from the human bronchial mucous membrane. 5. *Leucophrys patula*, a polygastric infusory animalcule: to show its surface covered with cilia, and the mouth surrounded by them.

This ciliary motion has been seen in different animals, on the external surface, in the alimentary canal, the respiratory system, the female generative organs; and in the cavities of the nervous system. It has not been observed, however, in the vagina; but may be traced from the lips of the os uteri through its cavity, and through the Fallopian tubes to their fimbriated extremities, and Virchow observed it over the surface of all the cerebral ventricles, but it was not marked

[1] Précis Élémentaire, i. 366.

[2] Sharpey, art. Cilia, Cyclop. of Anat. and Physiol., P. vi., p. 606, Lond., 1836; and Henle, Allgem. Anat., or Jourdan's French Translation, p. 251, Paris, 1843; and the excellent article Flimmerbewegung, by Valentin, in Wagner's Handwörterbuch der Physiologie, 3te Lieferung, S. 484, Braunschweig, 1842.

in the fourth ventricle. Kölliker,[1] however, sought for cilia in vain in the ventricular epithelium of an executed criminal. In the upper classes of animals, it is not witnessed on the external surface except in the embryo. In most animals, a high magnifying power is necessary to perceive it. A small piece of mucous membrane, on which it exists, should be moistened with water, and covered with a plate of glass, by which the membrane is spread out, and its border rendered clearly visible. With the aid of a powerful microscope, an appearance of undulation is perceptible, and small bodies floating in the water may be seen, near the border of the membrane, to be driven along in a determinate direction. With a still higher magnifying power, the cilia themselves may sometimes be recognized, although seldom very distinctly, owing to the great rapidity of their motion. The influence of the motion on the fluids and small bodies in contact with the membrane may be well exhibited by strewing a fine powder on the surface; as the motion of the cilia has a uniform direction, it gives rise to currents over the surface of the membrane.

Fig. 399.

Vibratile or Ciliated Epithelium.

a. Nucleated cells, resting on their smaller extremities. *b*. Cilia.

An easy mode of observing the phenomenon is to scrape with a knife a few scales of epithelium from the back of the throat of a living frog. If these be moistened with water or serum, they will continue to exhibit the motion of the adherent cilia for a very considerable time, if the epithelium be only kept moistened. On one occasion, Messrs. Todd and Bowman observed a piece of epithelium prepared in this manner exhibit motion for seventeen hours; and they thought it would probably have done so for a longer time had not the moisture around it evaporated. In the turtle, after death by decapitation, MM. Purkinje and Valentin found it lasted in the mouth nine days; in the trachea and lung, thirteen days; and in the œsophagus, nineteen days.[2]

According to M. Donné,[3] cilia are seen only on the "true mucous membranes" of his division,[4] or those that secrete an alkaline mucus. They are never met with on the acid membranes, which are analogous to the skin, and simple reflections of the cutaneous envelope. Hence, they are not found in the mouth or vagina, but in the nasal and bronchial mucous membrane.

The organs of ciliary motion are delicate transparent filaments, varying in length, according to Purkinje and Valentin, from $\frac{1}{12307}$ to $\frac{1}{1016}$ of an inch, and are generally thicker at the base than at the free extremity. Their motion continues after death as long as the tissues

[1] Goodsir's Annals of Anatomy and Physiology for May, 1852, No. 2, p. 113.

[2] Physiological Anatomy and Physiology of Man, by Messrs. Todd and Bowman, p. 62, Lond., 1843.

[3] Cours de Microscopie, p. 170, Paris, 1844.

[4] See Secretion of Mucus in vol. i., p. 502 of this work.

retain their contractility, and often much longer. Müller[1] thus sums up the present state of our knowledge in regard to the phenomenon. That the ciliary motion of the mucous membranes is due to the action of some unknown contractile tissue, which lies either in the substance of the cilia or at their base,—that this tissue resembles in contractility the muscular and other contractile tissues of animals;—that its properties so far agree with those of the muscular tissues—at all events with those of the involuntary muscles of the heart, and the vibratory laminæ of the lower crustacea;—that the motions, which it produces, continue without ceasing with an equable rhythm;—that its properties agree also with those of the muscular tissue of the heart in its motions, continuing long after the separation of the part from the rest of the animal body;—that this tissue differs essentially, however, from muscle, in the circumstance of its motions not being arrested by the local application of narcotics; and lastly, that the ciliary motion presents itself under conditions where it is not probable that a complicated organization exists,—namely, in the undeveloped embryos of polypiferous animals.

M. Donné[2] regards the cilia as animalcules; resembling in many respects the spermatozoids. They certainly resemble each other; but there is no sufficient reason to believe either of them animalcular.

The production of currents by the ciliary motion is not easy of explanation. Purkinje and Valentin ascribe them to the return of the cilia from the bent to the erect state, which gives an impulse to the fluid. The direction in which the cilia act is most commonly towards the outlet of the canal on which they are placed; but, as Mr. Paget[3] has remarked, their special purpose is in many instances—for example, in the ventricles of the brain—as uncertain as the power by which they act.

[1] Elements of Physiology, by Baly, P. iv. p. 866, Lond., 1838.
[2] Op. cit., p. 176. [3] Brit. and For. Med. Review, July, 1842, p. 264.

BOOK III.

REPRODUCTIVE FUNCTIONS.

THE functions, which we have been hitherto considering, relate exclusively to the individual. We have now to investigate those that refer to the preservation of the species, and without which living beings would soon cease to exist. Although these functions are really multiple, it has been the custom with physiologists to refer them to one head—*generation*—of which they are made to form the subordinate divisions.

CHAPTER I.

GENERATION.

THE function of generation, much as it varies amongst organized bodies, is possessed by them exclusively. When a mineral gives rise to another of a similar character, it is at the expense of its own existence; but the animal and the vegetable produce being after being without any curtailment of theirs.

The writers of antiquity considered, that all organized bodies are produced in one of two ways. Amongst the upper classes of both animals and vegetables, they believed the work of reproduction to be effected by a process, which is termed *univocal* or *regular generation*,—*generatio homogenea*, *propagatio;* but in the very lowest classes, as the mushroom, worm, frog, &c., they conceived that the putrefaction of different bodies, aided by the influence of the sun, might generate life. This has usually been termed *equivocal* or *spontaneous generation*,—*generatio heterogenea*, *æquivoca*, *primitiva*, *primigena*, *originaria*, *spontanea*. By some, however, *spontaneous generation* is made to include the production of living beings from the mere combination of inorganic elements; whilst by *equivocal generation* is meant their evolution from organized beings dissimilar to themselves, through irregularity in their functions, or the incipient decay or degeneration of their tissues. The doctrine of spontaneous generation is supposed to have been devised by the Egyptians to account for the swarms of frogs and flies, which appeared on the banks of the Nile after its periodical inundations.[1] Amongst the ancients, the latter hypothesis was almost universally credited. Pliny unhesitatingly expresses his belief, that the rat and frog are produced in this manner; and in his time it was generally thought, that the bee, for example, was derived at times from a parent;

[1] Fleming's Philosophy of Zoology, i. 24, Edinb., 1822.

but at others from putrid beef.[1] The passage of Virgil[2]—in which he describes how the shepherd Aristæus succeeded in producing swarms of bees from the entrails of a steer, exposed for nine days to putrefaction—is probably familiar to most readers, and exhibits the same belief.

The hypothesis of equivocal generation having been conceived in consequence of the impracticability of tracing ocularly the function in the minute tribes of animals, it naturally maintained its ground uninterruptedly, as regarded those animals, until better means of observation were invented. The difficulty of admitting regular generation as applicable to all animals was augmented by the fact, not at first known to naturalists, that many of the lower tribes conceal their eggs, in order that their nascent larvæ may find suitable food; but the existence of evident sexual organs in many of these small species induced physiologists, at an early period, to believe, that they also might be reproduced by sexual intercourse: direct proofs were not, however, obtained until the discovery of the microscope; after which the investigations of Redi, Vallisnieri, Swammerdam, Hooke, Réaumur, Bonnet, and others, clearly demonstrated, that many of the smallest insects have eggs and sexes, and reproduce like other animals. In the case of plants it has been supposed, that the growth of fungi amongst dung, and of the various parasitical plants that appear on putrid flesh, fruit, &c., furnishes facts in support of the equivocal theory; but the microscope exhibits the seeds of many of these plants, and experiments show them to be prolific. The characters, by which the different species and varieties are distinguished, although astonishingly minute, are fixed, exhibiting no fluctuation, such as might be anticipated did the plants arise by spontaneous generation, or by the fortuitous concourse of atoms.

The animalcules, that make their appearance in water in which vegetable or animal substances have been infused or are contained, would seem, at first sight, to favour the ancient doctrine. In these cases, however, the species, again, have determinate characters; presenting always the same proportion of parts; and appearing to transmit their vitality to their descendants in a manner not unlike animals and vegetables higher in the scale. The explanation, offered by the supporters of the univocal theory for those obscure cases, in which direct observation fails us, is, that their seeds and eggs are so extremely minute, that they can be borne about by the winds, or by birds; be readily deposited: and, when they find a soil or nidus favourable to their growth, undergo developement. Thus, the soil, in which alone the *monilia glauca* flourishes, is putrid fruit; whilst the small infusory animal—*vibrio aceti* or vinegar eel—requires, for its growth, vinegar that has been for some time exposed to the air.[3] "That the atmosphere," says Dr. Good,[4] "is freighted with myriads of insect eggs, that elude our senses; and that such eggs, when they meet with a proper bed, are hatched in a few hours into a perfect form, is clear to any one who has

[1] "Apes nascuntur partim ex apibus, partim ex bubulo corpore putrefacto."—Varro, De Re Rusticâ, iii. 16. See, also, Plinii Hist. Natural.

[2] Georgic., lib. iv. l. 295. See, also, J. B. Porta, Magiæ Naturalis libri viginti, cap. 2. "Animalia quædam terrestria, quæ ex putrefactione gignuntur." Lugd. Bat., 1644.

[3] Fleming, op. citat., p. 24. [4] Study of Medicine, Cl. i. Ord. 1, Gen. x. Sp. 3.

attended to the rapid and wonderful effects of what, in common language, is called a *blight*, upon plantations and gardens. I have seen, as probably many, who may read this work, have also, a hop-ground completely overrun and desolated by the *aphis humuli* or *hop green-louse*, within twelve hours after a *honey-dew* (which is a peculiar haze or mist, loaded with a poisonous miasm) has slowly swept through the plantation, and stimulated the leaves of the hop to the morbid secretion of a saccharine and viscid juice, which, while it destroys the young shoots by exhaustion, renders them a favourite resort for this insect, and a cherishing nidus for the myriads of little dots that are its eggs. The latter are hatched within eight-and-forty hours after their deposit, and succeeded by hosts of other eggs of the same kind; or, if the blight takes place in an early part of the autumn, by hosts of the young insects produced viviparously; for in different seasons of the year, the aphis breeds both ways. Now it is highly probable, that there are minute eggs or ovula of innumerable kinds of animalcules floating in myriads of myriads through the atmosphere, so diminutive as to bear no larger proportion to the eggs of the aphis than these bear to those of the wren, or the hedge-sparrow; protected, at the same time, from destruction by the filmy integument that surrounds them, till they can meet with a proper nest for their reception, and a proper stimulating power to quicken them into life; and which, with respect to many of them, are only found obvious to the senses in different descriptions of animal fluids. The same fact occurs in the mineral kingdom: stagnant water, though purified by distillation and confined in a marble basin, will, in a short time, become loaded on its surface or about its sides with various species of confervas; while the interior will be peopled with microscopic animalcules. So, while damp cellars are covered with boletuses, agarics and other funguses, the driest brick walls are often lined with the lichens and mosses. We see nothing of the animal and vegetable eggs or seeds by which all this is effected; but we know, that they exist in the atmosphere, and that this is the medium of their circulation." Any difficulty that might exist in regard to the transmission of such minute bodies through the atmosphere is removed, when we reflect on the extreme diffusion of odours, and on the fact that particles of sand are transmitted hundreds of miles from their original seat (see vol. i. p. 718). In dust, which was collected on a vessel three hundred miles from the land, Mr. Darwin[1] was much surprised to find particles of stone above the thousandth of an inch square, mixed with finer matter.

The view of the extraneous origin of the seeds of the confervæ, &c., is corroborated by an experiment of Senebier. He filled a bottle with distilled water, and corked it accurately; not an atom of green matter was produced, although it was exposed to the light of the sun for four years; nor did the green matter, considered as the first stage of spontaneous organization, exhibit itself in a glass of common water, covered with a stratum of oil. It is proper, however, to remark, that the observation of others invalidates the results of this experiment; and,

[1] Journal of Researches into the Natural History and Geology of the Countries visited during the Voyage of H. M. S. Beagle round the World, by C. Darwin, M. A., F. R. S., Amer. edit., p. 7, New York, 1846.

moreover, it has been said, that if the fact be admitted, the exclusion of air might have prevented some simple condition necessary for the aboriginal developement of life. Burdach,[1] assisted by Hensche, and along with Professor von Baer, poured water on marble in a glass vessel, the remainder of the vessel being filled with atmospheric air, oxygen or hydrogen; and placed it in the light of the sun, or in warm sand. No green matter was perceptible, but there was a slimy substance with white threads, part of which had a ramified appearance, and part that of coral. On the other hand, pieces of granite, newly broken from the midst of a block, produced—with fresh distilled water, and oxygen or hydrogen, in the sun—green matter, with threads of confervæ; but in the warmth of digestion flocculi only. He next took some mould, which he dug up, and which was inodorous, and apparently free from all foreign matter; boiled it in a considerable quantity of water, and reduced the decoction to the consistence of a thick, partly pulverulent extract. This gave, with common water and atmospheric air—in bottles with ground stoppers, tied over with bladder—in the sun, numerous infusory animalcules and green matter; but with distilled water and oxygen or hydrogen, green matter only appeared at the bottom of the bottles.

The subject of intestinal worms has been eagerly embraced by the supporters of the doctrine of equivocal generation, who are of opinion, that the germs need not be received from without; whilst the followers of the univocal doctrine maintain, that they must always be admitted into the system. The first opinion includes amongst its supporters the names of Needham,[2] Buffon, Patrin, Treviranus,[3] Rudolphi,[4] Bremser,[5] Himly, and other distinguished helminthologists. The latter comprises those who believe in the Harveian maxim,—the only one that can be admitted,—*omne vivum ex ovo*.[6] To support the latter opinion, it has been attempted to show, that the worms, found in the human intestines, are precisely the same as others that have been found out of the body; but the evidence in favour of this position is by no means strong or satisfactory. Linnæus affirms, that *tænia vulgaris*,—of a smaller size, however,—has been met with in muddy springs; and *ascarides vermiculares* in marshes, and the putrescent roots of plants. Gadd affirms, that he met with *tænia articulata plana osculis lateralibus geminis* in a chalybeate rivulet; Unzer, *tænia* in a well; and Tissot says, that he found *tænia*, exactly like the human, in a river; whilst Linnæus, Leeuenhoek, Schäffer and others affirm, that they have found *distoma hepaticum* in water; but O. F. Müller,—who took extraordinary pains in the comparative examination of the entozoa that infest the human body, and those met with in springs,—states, that he has frequently detected *planariæ*, but never saw one like the *distoma hepaticum*.[7]

[1] Die Physiologie als Erfahrungswissenschaft, 2te Auflage, i. 23, Leipz., 1835.
[2] An Account of some New Microscopical Discoveries, 8vo., Lond., 1745.
[3] Biologie, ii. 264.
[4] Entozoorum sive Vermium Intestinalium Historia Naturalis, i. 370.
[5] Ueber Lebende Würmer im Lebenden Menschen, Wien, 1819.
[6] "La vie ne naît que de la vie. Tout être vivant vient d'un parent." Flourens, De la Longévité Humaine et de la Quantité de Vie sur le Globe, 2de édit., p. 166, Paris, 1855.
[7] Rudolphi, op. citat.

On the other hand, the supporters of the equivocal theory have laboured, with a good deal of success, to show, that a difference is always discoverable between the worms found without, and those found within, the body; but were it demonstrated to a mathematical certainty, that such difference exists, it would not be an invincible argument against the correctness of the univocal theory; as differences of locality, food, &c., might induce important changes in their corporeal developement, and give occasion to the diversity occasionally perceptible amongst these parasites. Yet if we admit, that the germs of the entozoa are always received from without, their occurrence in different stages of developement in the fœtus in utero is a circumstance difficult of explanation. Small, indeed, must be the germ, which, when received into the digestive organs of the mother, can pass into her circulation, be transmitted into the vessels of the fœtus; be deposited in some viscus, and there undergo its full developement; yet such cases have occurred, if the theory be correct. Certain it is,—howsoever the fact may be accounted for,—that worms have been found in the fœtus by individuals whose testimony cannot be doubted. Eschholz saw them in the egg of the hen. Fromann found *distoma hepaticum* in the liver of the fœtal lamb; Kerckring,[1] *ascarides lumbricoides* in the stomach of a fœtus six and a half months old; Brendel, *tæniæ* in the human fœtus in utero; Heim, *tæniæ* in the new-born infant; Blumenbach, *tæniæ* in the intestine of the new-born puppy; and Göze, Bloch, and Rudolphi, the same parasite in sucking lambs.

Perhaps the conclusion of Cuvier[2] is most consistent with analogy, —that these parasites "propagate by germs so minute as to be capable of transmission through the narrowest passages; so that the germs may exist in the infant at birth." We have seen, however, that not simply the germs, but the animals themselves have been found at this early period of existence. The scientific world was, at one time, astounded by the assertion of Mr. Crosse, that he had succeeded in forming infusory animalcules from solutions of granite, silex, &c., by the aid of galvanism. He was engaged in some experiments on crystallization, in which a powerful galvanic battery was made to act upon a saturated solution of silicate of potassa, when the insects made their appearance. He subsequently employed nitrate of copper—a poison to mammalia— and from it also the insects emerged. Some years afterwards, these experiments were repeated by Mr. Weekes, of Sandwich, England, and with the same results. Besides employing silicate of potassa, Mr. Weekes tried ferrocyanuret of potassium, on account of its containing a larger proportion of carbon, a principal element of organized bodies; and from this the insects were produced in increased numbers. The insects observed by both experimenters appear to have been the same—a species of acarus, minute, semi-transparent, and furnished with long bristles, which can only be seen by the aid of the microscope.

The only satisfactory mode of explaining the phenomenon—difficult

[1] Spicilegium Anatom. Obs., lxxix. p. 154, Amstel., 1670.

[2] Règne Animal, p. 27. See, also, Vogel, The Pathological Anatomy of the Human Body, by Day, p. 454, Lond., 1847, or Amer. edit., Philad., 1847.

of conception under any aspect—is, that ova were existent in the solutions, which became developed under the galvanic influence. It has been plausibly argued, however, that the *Acarus Crossii* was a type of being ordained from the beginning, and destined to be realized under certain physical conditions. "When a human hand," observes an ingenious and able writer,[1] "brought these conditions into the proper arrangement, it did an act akin to hundreds of familiar ones which we execute every day, and which are followed by natural results; but it did nothing more. The production of the insect, if it did take place as assumed, was as clearly an act of the Almighty himself, as if he had fashioned it with his hands. For the presumption, that an act of aboriginal creation did take place, there is this to be said, that, in Mr. Weekes's experiments, every care that ingenuity could devise, was taken to exclude the possibility of a developement of the insects from ova. The wood of the frame was baked in a powerful heat; a bell-shaped glass covered the apparatus, and from this the atmosphere was excluded by the constantly rising fumes from the liquid, for the emission of which there was an aperture so arranged at the top of the glass, that only these fumes could pass. The water was distilled and the substance of the silicate had been subjected to a white heat. Thus, every source of fallacy seemed to be shut off. In such circumstances, a candid mind, which sees nothing impious or unphilosophical in the idea of a new creation, will be disposed to think, that there is less difficulty in believing in such a creation having actually taken place, than in believing that in two instances, separated in time and place, exactly the same insects should have chanced to arise from concealed ova, and these a species heretofore unknown." For years, we are informed,[2] Mr. Weekes continued to subject solutions to electric agency, and invariably found insects produced in them, whilst they as invariably failed to appear where electric action was not employed, but every other condition was fulfilled. It is stated, however, in answer to these experiments, that specimens of the insects were sent to Paris, and found to contain ova; and that other specimens sent to London were dicovered not to be a new species, but one abundant in the country,—"the *acarus horridus*, which abounds in dirty shops, dusty shelves, and damp outhouses; and having a taste for pure physics, is especially abundant in all laboratories, and among the bottles of a chemist's shop."![3]

Another series of facts has been brought forward as deserving not less attention than those already mentioned, and which would seem to show, that new species of animals may result from new circumstances. The pig, in its domestic state, is subject to the attacks of hydatids, from which the wild animal is free, and which constitute the "measles" in pork; and it is argued that as the domestication of the pig is comparatively a recent event, the hydatid must likewise be of recent origin. So, also, there is a tinea, which attacks dressed wool, but never touches it in its unwashed state. A particular insect disdains all food but

[1] Vestiges of the Natural History of Creation, Amer. edit., p. 143, New York, 1845.
[2] Sequel to Vestiges of the Natural History of Creation, p. 85, New York, 1846.
[3] Edinburgh Review, for July, 1845, Amer. edit., p. 38.

chocolate, and the larva of the *oinopota cellaris* lives no where but in wine and beer—all articles manufactured by man.[1] The subject is involved in difficulties; yet the univocal theory is, in all respects perhaps, most admissible as regards the whole living creation. "That all animals are produced from eggs (*omne vivum ex ovo*)," says Professor Agassiz,[2] "is an old adage in zoology, which modern researches have fully confirmed." Still, there are many distinguished naturalists who esteem it probable, that spontaneous generation may occur in the lowest divisions of the animal series. Amongst these may be mentioned De Lamarck, Raspail, Burdach, Treviranus, Wrisberg, Schweigger, Gruithuisen, Von Baer,—and M. Adelon seems to accord with them. The facts that have been observed, of late, of certain parasites, as the Cercaria, insinuating themselves into the skin and cavities of animals, as well as phenomena like the following, are favourable to the former view. At certain periods of the year, the sculpins of the Baltic are infested by a particular species of tænia, from which they are free at other seasons. Mr. Eschricht observes, that at certain seasons these worms lose a great portion of the long chain of rings of which they are composed; and on a careful examination each ring is found to contain several hundred eggs, which, on being freed from their envelope, float in the water, and are doubtless swallowed by the sculpins, in which, finding a nidus favourable to their developement, the species is propagated, and transmitted from one generation of the fish to another.[3] All animals may swallow, in like manner, in their food and the water they drink, numerous eggs of parasites, which may become developed internally when the nidus is favourable to them; and it is probable that the intestines of man afford such a nidus only for the entozoa with which he is known to be infested; and hence we can account for the different parasites that are met with in different animals.[4]

The views of M. De Lamarck[5] regarding the formation of living bodies are strange in the extreme; and exhibit, what we so frequently witness, that, in order to get rid of a subject difficult of comprehension, the philosopher frequently adopts suppositions, that require a much greater sketch of the imagination to invent, and present stronger obstacles to belief, than those for which they may have been substituted. M. De Lamarck maintains, that the first organized beings were formed throughout by a true spontaneous generation,—their existence being owing to an excitative cause of life, furnished probably by the circumambient medium, and consisting of light and electric fluid. When this cause meets with a substance of a gelatinous consistence, dense enough to retain fluids, it organizes it into areolar tissue; and a living being results. This process, according to De Lamarck, is occurring daily at the extremity of the vegetable and animal kingdoms. The being, thus formed, manifested originally, according to him, three faculties of life,—nutrition, growth, and reproduction; but only in the most simple

[1] Vestiges, &c., p. 139.
[2] Principles of Zoology, by Louis Agassiz and Augustus A. Gould, p. 103, Boston, 1848.
[3] Ibid., p. 141.
[4] See, on the whole subject of the origin of life—*Ursprung des Lebens*—Eschricht, Das Physische Leben, S. 98, Berlin, 1852.
[5] Philosophie Zoologique, vol. i., Paris, 1830

manner. The organization soon, however, became more complicated, for it is, he remarks, a property of the vital movement to tend always to a greater degree of developement of organization; to create particular organs, and to divide and multiply the different centres of activity; and, as reproduction has constantly preserved all that had been acquired, numerous and diversified species have in this manner been formed, possessing more and more extensive faculties. So that, according to this system, nature was directly concerned only in the first draughts of life; and participated indirectly in the existence of living bodies of a more complex character; and these proceeded from the former, after a lapse of an enormous time, and an infinity of changes in the incessantly increasing complication of organization;—reproduction continuing to preserve all the acquired modifications and improvements.

The simplest kind of generation does not require sexual organs. The animal, at a certain period of existence, separates into several fragments, which form so many new individuals. This is called *fissiparous generation* or *generation by spontaneous division*. We have examples of it in the infusory animalcules,—as in *vibrio aceti*, the vinegar eel. A somewhat more elevated kind of reproduction is the *gemmiparous*,—common in the vegetable kingdom,—which consists in the formation of buds, sporules, or *germs* on some part of the body. These, at a particular period, drop off, and form as many new individuals; and, according as the germs are developed at the surface of the body, or internally, gemmiparous generation is said to be *external* or *internal*. In these two varieties, the whole function is executed by a single individual. Higher up in the scale, we find special organs—*male* and *female*—for the accomplishment of generation. In animals, however, that possess special reproductive organs, some have both sexes in the same individual or are *hermaphrodite* or *androgynous*, as is the case with almost all plants, and some of the lower tribes of animals. In these, again, we notice a difference. Some are capable of reproduction without the concourse of a second individual; others, although possessing both attributes, require the concourse of another; the male parts of the one uniting with the female parts of the other. Both, in this way, become impregnated. The *helix hortensis* or *garden snail* affords us an instance of this kind of reproduction. They meet in pairs, according to Shaw,[1] and, stationing themselves an inch or two apart, launch several small darts, not quite half an inch long, at each other. These are of a horny substance, and sharply pointed at one end. The animals, during the breeding season, are provided with a little reservoir for them, situate within the neck, and opening on the right side. On the discharge of the first dart, the wounded snail immediately retaliates on its aggressor by throwing a similar dart; the other renews the battle and is wounded in turn. When the darts are expended, the war of love is completed, and its consummation succeeds.

In the superior animals, each sexual characteristic is possessed by a separate individual,—the species being composed of two beings, male and female; and the concourse of the two, or of matters proceeding

[1] Zoology, or Systematic Natural History, Lond., 1800.

from them, being absolutely necessary for reproduction. But here, again, two great differences are met with in the process. Sometimes the fecundating fluid of the male is not applied to the ovum of the female, until after its ejection by the latter, as in fishes.[1] In other cases, the ovum cannot be fecundated after its ejection, and the fluid of the male sex is applied to it whilst still within the female—as in birds and the mammalia. In such case, the male is furnished with an organ for penetrating the parts of the female, and in this kind of generation there must be *copulation*.

Again, where there is copulation, the following varieties may exist. *First.* The ovum, when fecundated, may be immediately laid by the female, and be hatched out of the body,—constituting *oviparous generation*. *Secondly.* Although the process of laying may commence immediately, the fecundated ovum may pass so slowly through the excretory passages that it may be hatched there; and the new individual issue from the womb of the parent possessing the proper formation. This constitutes *ovo-viviparous generation*, of which we have examples in the viper and salamander. *Thirdly.* The fecundated ovum may be detached from the ovary soon after copulation; but, in place of being ejected, may be deposited in a reservoir, termed a *womb* or *uterus;* be fixed there; attract fluids from the organ adapted for its developement; and thus, increasing at the expense of the mother, be hatched, as it were, in this reservoir so that the new being may be born under its appropriate form. In such case, it may be supported for a time, after birth, on a secretion of the mother—the milk. These circumstances constitute *viviparous generation;* in which there are copulation, fecundation, gestation or pregnancy, and lactation or suckling. *Lastly.* There are animals, which, like the kangaroo, opossum, and wombat, are provided with abdominal pouches—*marsupia*—into which the young, born at a very early stage of developement, are received; and nourished with milk secreted from the glands contained within these pouches. Such animals are termed *marsupial* or *marsupiate.*

There is much difference in animals as regards the nurturing care afforded by the parents to their young. Amongst oviparous animals, many are satisfied with instinctively depositing their ova in situations and under circumstances favourable to their being hatched, and abandoning them, so that they can never know their progeny. This is the case with insects. Others, again, as birds, subject their ova to incubation; and, after they have been hatched, administer nourishment to their young during the early period of existence. In the viviparous animal, these cares are still more extensive,—the mother drawing from her own bosom the nutriment needed by the infant, or *suckling* it.

[1] The artificial fecundation of fish has of late years received much attention, with the view of introducing valuable species into streams where they have not previously existed, or do not abound. It is but necessary, that the roe of the female, and the melt of the male, shall be brought in contact under favourable circumstances. Professor Coste, who has been employed by the French government on the important subject of pisciculture, exhibited to the author, in the summer of 1854, numerous salmon, in various stages of their growth, which had been raised by him in this manner. Instructions Pratiques sur la Pisciculture suivies de Mémoires et de Rapports sur le Même Sujet. Par M. Coste, Membre de l'Institut, &c., Paris, 1853. Translated by W. H. Fry, New York, 1854.

There are yet other varieties in the generation of animals. In some, it can be performed but once during the life of the individual; in others, it can be effected repeatedly. At times, one copulation fecundates only a single individual; at others, several generations. A familiar example of this fecundity occurs in the common fowl, in which a single access may be sufficient to fecundate the eggs for a season. In the insect tribe, this is still more strikingly exemplified. In the *aphis puceron* or *green plant louse*, through all its divisions; and in the *monoculus pulex*, according to naturalists, a single impregnation suffices for at least six or seven generations. There is, in this case, another strange deviation from the ordinary laws of propagation,—that in the warm summer months the young are produced viviparously; and in the cooler autumnal months oviparously. A single impregnation of the queen bee serves to fecundate all the eggs she may lay for two years at least,—Huber[1] believes for the whole of her life, but he has had numerous proofs of the former. She begins to lay her eggs forty-six hours after impregnation; and commonly lays about three thousand in two months, or at the rate of fifty daily. The young, again, are sometimes born with the shape they have always to maintain; at others, under forms that are subsequently modified materially, as in the *papilio* or *butterfly* genus;—and, *lastly;*—many naturalists admit a series of cases in which the young not only do not resemble the parent at birth, but remain dissimilar during their whole life, so that their relationship is not apparent until a succeeding generation. The son resembles not the father, but the grandfather; and in some cases the resemblance does not reappear until the fourth or fifth generation, and even later. This strange variety of propagation has received the name of *alternate reproduction* or *generation* and *metagenesis*.[2] The phenomena presented by it have been much studied of late, by Professors Agassiz, Carpenter,[3] and others. Among the parasitic worms is one known under the name Cercaria, which attaches itself to fresh-water shells, particularly the Lymnea and Paludina; and soon becomes changed into the Distoma or Fluke; so that the Cercaria can only be considered as the larve of the Distoma; and farther investigation exhibits even larves to the Cercaria themselves. Among the aphides the number of generations is still greater. The first generation, which is produced from eggs, soon undergoes metamorphosis, and gives birth to a second generation, which is followed by a third, and so on; so that it is not at times until the eighth or ninth generation, that the perfect animal appears as male and female,—the sexes being for the first time distinct, and the male provided with wings. The female lays eggs, which are hatched the following year to undergo a similar succession.[4]

It has been recently proved experimentally by Küchenmeister,[5] that cysticercus cellulosæ becomes transformed into tænia solium in

[1] Nouvelles Observations sur les Abeilles, Paris, 1814.

[2] Steenstrup on the Alternation of Generations (*Generations Wechsel*), English edition by the Ray Society, London, 1845.

[3] Principles of Comparative Physiology, Amer. edit., p. 481, Philad., 1854.

[4] Agassiz and Gould, op. cit., p. 131. See, also, Allen Thomson, art. Ovum, in Cyclop. of Anat. and Physiol., pt. xliii., p. 24, September, 1852.

[5] Correspond. Blatt. der Verein. für gemein. Arbeit. S. 158, No. 13, 1855; and Brit. and For. Med.-Chir. Rev., Jan., 1856, p. 238.

the intestinal tube of man. A criminal received with his food a number of cysticerci, 72, 60, 36, 24 and 12 hours before his death. On examining his body, forty-eight hours after execution, ten young tæniæ were found in the duodenum.

Reproduction in the human species requires the concourse of both sexes; the sexes being separate, and each possessed by a distinct individual—*male* and *female.* All the acts comprising it may be referred to five great heads. 1. *Copulation*, the object of which is to apply the fecundating germ, furnished by the male, to that of the female. 2. *Conception* or *fecundation*, the prolific result of copulation. 3. *Gestation* or *pregnancy*, comprising the sojourn of the fecundated ovum in the uterus, and the developement it undergoes there. 4. *Delivery* or *accouchement*, which consists in the detachment of the ovum; its excretion, and the birth of the new individual: and lastly, *lactation*, or the nourishing of the infant on the maternal milk.

1. GENERATIVE APPARATUS.

The part, taken by the two sexes in the process of generation is not equally extensive. Man has merely to furnish the fluid necessary for effecting fecundation, and to convey it within the female. He, consequently, participates only in copulation and fecundation; whilst, in addition, the acts of gestation and lactation are accomplished by the female. Her generative apparatus is therefore more complicated, and consists of a greater number of organs.

a. *Genital Organs of the Male.*

The generative apparatus of the male comprises two orders of parts: —1. Those which secrete and preserve the fecundating fluid, and those which accomplish copulation. The first consists of two similar glands—*testes*—which secrete the *sperm* or fecundating fluid from the blood. 2. The excretory ducts of those glands—*vasa deferentia.* 3. The *vesiculæ seminales*, which communicate with the vasa deferentia and urethra; and 4. Two canals, called *ejaculatory*, which convey the sperm from the vesiculæ seminales into the canal of the urethra, whence it is afterwards projected externally. The second consists of the *penis*, an organ essentially composed of erectile tissues, and capable of acquiring considerable rigidity. The several parts will require a more detailed notice.

Testes.—The testicles are two glands situate in a bag suspended beneath the pubes, called *scrotum;* the right being a little higher than the left. They are of an ovoid shape, compressed laterally,—their size being usually that of a pigeon's egg, and weight about seven and a half or eight drachms:—Sir A. Cooper[1] says about an ounce; and Mr. Curling[2] six drachms. The left testis is generally larger than the right. Like other glands, they receive arterial blood by an appropriate vessel, which communicates with the excretory duct. The *spermatic artery* conveys the blood, from which the secretion has to be formed, to the testicle. It arises from the abdominal aorta at a very

[1] Observations on the Structure and Diseases of the Testis, Amer. edit., p. 25, Philad., 1845.

[2] Practical Treatise on Diseases of the Testis, &c., p. 9, Lond., 1843.

acute angle; is small, extremely tortuous, and passes down to the abdominal ring, through which it proceeds to the testicle. When it reaches this organ, it divides into two sets of branches, some of which are distributed to the epididymis, and others enter the testicle at its upper margin, and assist in constituting its tissue. The excretory ducts in the testicle form what are called the *seminiferous vessels* or *tubuli seminiferi.* These terminate in a white cord or nucleus—situate at the upper and inner part of the organ, where the excretory duct commences—which is called *corpus Highmorianum* or *sinus of the seminiferous vessels.* Besides these anatomical elements of the testes, there are also—1. Veins, termed *spermatic*, which return the superfluous blood to the heart. These arise in the very tissue of the organ, and form the *spermatic plexus*, the divisions of which collect in several branches, that pass through the abdominal ring, and unite into a single trunk, which subsequently divides again into another plexus, termed *corpus pampiniforme.* This has been described as peculiar to the human species, and as a diverticulum for the blood of the testicle, whose functions are intermittent. These veins ultimately terminate on the right side in the vena cava, and on the left in the renal vein. 2. Lymphatic vessels, in considerable number, the trunks of which, after having passed through the abdominal ring, open into the lumbar glands. 3. Nerves, partly furnished by the renal and mesenteric plexuses and by the great sympathetic, partly by the lumbar nerves, and which are so minute as not to be traceable as far as the tissue of the testicle. 4. An outer membrane or envelope to the whole organ, called *tunica albuginea* or *peritestis.* This is of an opaque white colour and of an evidently fibrous and close texture; it envelopes and gives shape to the organ, and sends into the interior of the testicle numerous filiform, flattened prolongations, which constitute incomplete septa. These form triangular spaces, filled with seminiferous vessels, which pass, with considerable regularity, towards the superior margin and corpus Highmorianum.

These elements united constitute the testicle, the substance of which is soft, of a yellowish-gray colour, and divided by prolongations of the tunica albuginea, and the tunica vasculosa of Sir A. Cooper, into a number of lobes and lobules. It seems to be formed of an immensity of very delicate, tortuous filaments, interlaced and convoluted in all directions, loosely united, between which are ramifications of the spermatic arteries and veins.

According to Dr. Monro, secundus,[1] the seminiferous tubes of the testicle do not exceed the $\frac{1}{200}$th part of an inch in diameter, and when filled with mercury, the $\frac{1}{120}$th part. He calculated, that the testis consists of 62,500 tubes, supposing each to be one inch long; and that if the tubes were united they would be 5208 feet four inches long. Lauth estimates their length at 1750 feet, and Krause at 1015. The tubuli seminiferi finally terminate in straight tubes, called *vasa recta*, which unite near the centre of the testis in a complicated arrangement, bearing the name *rete testis* or *rete vasculosum testis:* from this from 12 to 18 ducts proceed upwards and backwards to penetrate the corpus

[1] Elements of the Anat. of the Human Body, by Monro (tertius), ii. 179, Edinb., 1825.

Highmorianum and tunica albuginea. These ducts are called *vasa efferentia*. Each of them is afterwards convoluted upon itself, so as to form a conical body, called *conus vasculosus*, having its base backwards; and at its base, the tube of each cone enters the tube of which the epididymis is formed. The epididymis is the prismatic arch, B, C, Fig. 400, which rests vertically on the back of the testicle, and adheres to it by the reflection of the tunica vaginalis, so as to appear a distinct part from the body of the testis. It is enlarged at both ends;—the upper enlargement being formed by the coni vasculosi, and called *globus major;* the lower called *globus minor*. The epididymis is formed by a single convoluted tube, a fourth of a line in diameter. When the tube attains the lower end of the globus minor, it becomes less convoluted, enlarges, turns upwards, and obtains the name *vas deferens*.

Into the angle made by the epididymis, where it terminates in the vas deferens, is poured the secretion of the appendix or *vasculum aberrans*, which closely resembles a single lobule in structure. Its use is unknown.

The marginal figures exhibit the arrangement of the testis and its ducts.

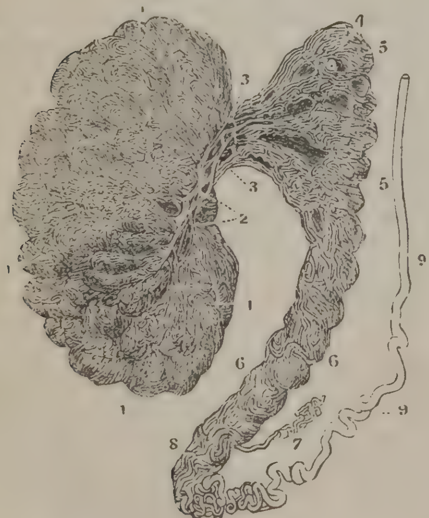
The testes of most animals, that procreate but once a year, are comparatively small during the months when they

Fig. 400.

Male Organs.

Left Hand Fig. Testicle covered by its membranes, and seeming like one body. *Right Hand Fig.* Testicle freed from its outer coat. A. Body of testicle. B. Commencement of epididymis, or *globus major*. C. Small head, or *globus minor*. D. *Vas deferens.*

Fig. 401.

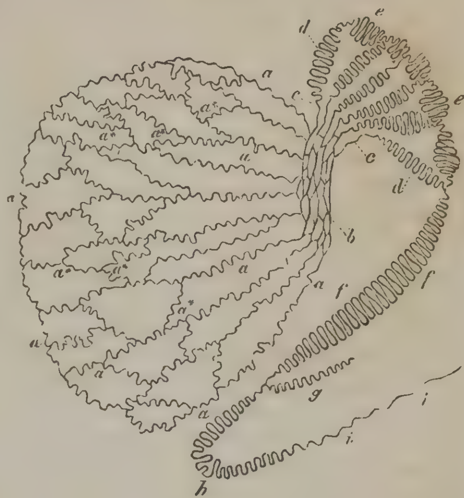


Human Testis injected with Mercury.

1, 1. Lobules formed of seminiferous tubes. 2. Rete testis. 3. Vasa efferentia. 4. Plexuses of efferent vessels passing into the head of the epididymis 5, 5. 6. Body of epididymis. 7. Its appendix. 8. Its tail or cauda. 9. Vas deferens.

are not excited. In man, the organ before birth, or rather during the greater part of gestation, is an abdominal viscus; but, about the seventh month of fœtal existence, it gradually descends through the abdominal ring into the scrotum, which it reaches in the eighth month by a mechanism to be described hereafter. In some cases it never descends, but remains in the cavity of the abdomen, giving rise to considerable mental distress in many instances; and exciting the idea, that there may be a total absence of the organs, or that if they exist they cannot effect the work of reproduction. The uneasiness is needless, provided there be other evidences of virility,—the descent appearing to be by no means essential. It has been sufficiently demonstrated, that individuals, so circumstanced, are capable of procreation. Few opportunities have occurred for observing the condition of the testes in such cases after death; but these have not exhibited any morphological defect, which could lead to the belief, that they were incapable of executing their functions. The genital organs of a gentleman, who committed suicide on account of the non-descent of the testes, are in the Museum of Guy's Hospital, London. Mr. Curling[1] examined the preparation, and found the testes, both of which were within the abdomen close to the internal ring, nearly, if not quite, the natural size; and it is stated, that the ducts contained sperm. In many animals, the testicles are always internal; whilst, in some, they appear only in the scrotum during the season of amorous excitement. M. Foderé has indeed asserted, that the *crypsorchides* or *testicondi*,—those whose testes have not descended,—are occasionally remarked for the possession of unusual prolific powers and sexual vigour.[2] Dr. Marshall states, that in the examination of 10,800 recruits he found 5 in whom the right, and 6 in whom the left testicle

Fig. 402.



Plan of the Structure of the Testis and Epididymis.

a, *a*. Tubuli seminiferi. *a**, *a**. Their anastomoses. *b*. Rete testis. *c*. Vasa efferentia. *d*, *d*. Plexus of efferent vessels passing into the head of the epididymis. *e*, *e*, *f*. Body of epididymis. *g*. Its appendix. *h*. Its tail or cauda. *i*, *i*. Vas deferens.

[1] Art. Testicle, in Cyclopædia of Anatomy and Physiology, Pt. xxxviii. p. 990, Feb., 1850.

[2] "Ces organes paraissant tirer du bain chaud où ils se trouvent plongés plus d'aptitude à la sécrétion que lorsqu'ils sont descendus au dehors dans leurs enveloppes ordinaires!"—*Traité de Médecine Légale*, i. 370, Paris, 1813.

was not apparent. He met with but one instance in which both testicles had not descended.[1]

It appears that there is a set of barbarians at the back of the Cape of Good Hope, who are generally possessed of but one testicle, or are *monorchides;* and Linnæus, under the belief, that this is a natural defect, has made them a distinct variety of the human species. Sir John Barrow noticed the same singularity; but Dr. Good[2] thinks it doubtful, whether, like the want of beard amongst the American savages, the destitution may not be owing to a barbarous custom of extirpation in early life. The deviation is not, however, more singular than the unusual formation of the nates and genital organs of the female in certain people of those regions, to which we have referred elsewhere.

The possession of a single testicle appears to be sufficient for procreation. Occasionally three exist. At times, they are extremely small, but capable of executing all their functions. Mr. Wilson[3] was consulted by a gentleman, on the point of marriage, respecting the propriety of his entering into that state, whose penis and testicles very little exceeded in size those of a youth of eight years of age. He was twenty-six years old, but had never experienced sexual desire until he became acquainted with the lady whom he proposed to make his wife; after which he had repeated erections, with nocturnal emissions. He married; became the father of a family; and when twenty-eight years old the organs had increased to the usual size of those of the adult.

In certain cases, the testes are drawn up against the abdominal ring so as to encourage the idea, that there are none in the scrotum. Professor Gross[4] has given the cases of two boys, one fourteen, the other eleven years of age, who were said to have been castrated; and a medical practitioner deposed to the absence of the testes; which, however, were found in the groin, a little below the external ring, whence, by a little traction, they could be easily drawn down into the scrotum.

The testicle is connected with the abdominal ring by means of the *spermatic cord*, a fasciculus of about half an inch in diameter, which can be readily felt through the skin of the scrotum. It is formed essentially of the vessels and nerves that pass to or from the testicles;—the spermatic artery, spermatic veins, lymphatics, and nerves of the organ, and the vas deferens, or excretory duct. These are bound together by means of areolar tissue; and, externally, a membranous sheath of a fibrous character envelopes the cord, and keeps it distinct from the surrounding parts, and especially from the scrotum. When the cord has passed through the abdominal ring, its various elements are no longer held together, but each passes to its special destination.

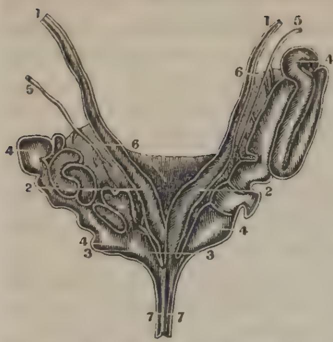
The *scrotum* or *purse* is a continuation of the skin of the inner side of the thighs, perineum, and penis. It is symmetrical, the two halves being separated by a median line or *raphe*. The skin is of a darker colour here than elsewhere; rugous; studded with follicles, and sparingly furnished with hair. This may be considered its outermost coat.

[1] Hints to Young Medical Officers in the Army, p. 83.
[2] Physiological Proem to class Genetica, Study of Medicine, vol iv.
[3] Lectures on the Structure and Physiology of the Male Urinary and Genital Organs, &c., London, 1821.
[4] Western Journal of Medicine and Surgery, May, 1841, p. 355.

Beneath this is the *dartos*,—a reddish, areolar membrane, which forms a distinct sac for each testicle; and a septum—*septum scroti*—between them. Much discussion has taken place regarding the nature of the dartos; some supposing it to be muscular, others areolar. Breschet and Lobstein affirm, that it does not exist in the scrotum before the descent of the testes, and, with more recent anatomists, they consider it to be formed by the expansion of the gubernaculum testis. Meckel, however, suggests, that it constitutes the transition between the areolar and muscular tissues, and that there exists between it and other muscles the same relation as between the muscles of the superior and inferior animals. It consists of long fibres considerably matted together, and passing in every direction, but which are easily separable by distension with air or water, and by slight maceration. The generality of anatomists conceive it to be of an areolar character, yet it is manifestly contractile; corrugates the scrotum, and doubtless consists of muscular tissue also; Professor Horner,[1] indeed, affirms, that he dissected a subject in January, 1830, in which the fibres were evidently muscular, although interwoven. Beneath the dartos a third coat exists, which is muscular:—it is called *cremaster* or *tunica erythroïdes;* arises from the lesser oblique muscle of the abdomen; passes through the abdominal ring; aids in the formation of the spermatic cord, and terminates insensibly on the inner surface of the scrotum. It draws the testicle upwards. The areolar substance, that connects the dartos and cremaster with the tunica vaginalis, has been considered by some as an additional coat, and termed *tunica vaginalis communis.* The *tunica vaginalis* or *tunica elytroïdes*, is a serous membrane, enveloping the testicle and lining the scrotum; having, consequently, a scrotal and a testicular portion. We shall see, hereafter, that it is a dependence of the peritoneum, passing before the testicle in its descent, and afterwards becoming separated from any direct communication with the abdomen. The *vas deferens* or excretory duct of the testicle commences at the globus minor of the epididymis, (C, Fig. 400,) itself formed of a convoluted tube. This, when unfolded, according to Monro, measures thirty-two feet. As soon as the vas deferens quits the testicle, it joins the spermatic cord; passes upwards to the abdominal ring; separates from the bloodvessels on entering the abdomen, and descends downwards and inwards to the posterior and inferior part of the bladder, passing between the *bas-fond* of the latter and the ureter. It then converges towards its fellow along the under extremity of the bladder, at the inner margin of the vesicula seminalis of the same side, and ultimately opens into the urethra near the neck of the bladder. At the base of the prostate, it receives a canal from the vesicula, and continues its course to the urethra under the name of *ejaculatory duct.* The vas deferens has two coats, the outer of which is very firm and almost cartilaginous; but its structure is not manifest; the inner thin, and belonging to the class of mucous membranes. The *vesiculæ seminales*, Fig. 403, 4, 4, are considered to be two convoluted tubes,—one on each side,—which are two inches or two inches and a half long, and six or seven lines broad at the fundus, and are situate at the lower fundus of the bladder, between it and the rectum, and behind the prostate gland. At the anterior extremi-

[1] Special Anat. and Histology, 7th edit., ii. 116, Philad., 1846.

Fig. 403.



Vertical Section of the Union of Vas Deferens and Vesiculæ Seminales so as to show their Cavities.

1, 1. Vas deferens with thick parietes and narrow cavity. 2, 2. Portion of the same where the cavity is enlarged. 3, 3. Extremities of vas deferens from each side where they join the vesiculæ seminales and ductus ejaculatorius. 4, 4. Vesiculæ seminales distended with air and dried. 5, 5. Arteries to the vesiculæ. 6. Portion of the peritoneum covering the posterior part of the vesiculæ. 7. Ejaculatory ducts.

ties they approach each other very closely, being separated only by the vasa deferentia. When inflated and dried, they present the appearance of cells; but are generally conceived to be tubes, which, being convoluted, are brought within the compass of the vesiculæ. When dissected and stretched out, they are four or five inches long by about one-fourth of an inch in diameter. M. Amussat,[1] however, denies this arrangement of the vesiculæ, and affirms, that he has discovered them to be formed of a minute canal of considerable length, variously convoluted, the folds of which are united to each other by cellular filaments, like those of the spermatic vessels. At the anterior part, termed the *neck*, a short canal passes off, which unites at an acute angle with the vas deferens, to form the *ductus ejaculatorius*. Between the openings of the ejaculatory ducts at the lateral and anterior part of the verumontanum, there is often a depression, sometimes of a large size, which is termed *utriculus*, *vesica* seu *vesicula prostatica* and *sinus pocularis*, and has been regarded as the analogue to the uterus in the female.[2] The vesiculæ are formed of two membranes; the more external like that of the vas deferens, and capable of contracting in the act of ejaculation; and an internal mucous lining, of a white, delicate character, a little like that which lines the interior of the gall-bladder. The vesiculæ are manifestly contractile, owing to unstriped muscular fibres in their second coat. They are filled, in the dead body, with an opaque, thick, yellowish fluid, very different in appearance from the sperm ejaculated during life.[3]

The *prostate gland* is an organ of very dense tissue, embracing the neck of the bladder, and penetrated by the urethra, which traverses it much nearer its upper than lower surface. The base is directed backwards; the point forwards, and its inferior surface rests upon the rectum, so that, by passing the finger into the rectum, enlargements of the organ may be detected. The prostate was once universally esteemed glandular, and is still so termed; but it is generally and correctly regarded as an agglomeration of several small follicles, filled by a viscid whitish fluid. These follicles have numerous minute excretory ducts, which open on each side of the caput gallinaginis.

The *glands of Cowper* are two small, oblong bodies; of the size of a pea; of a reddish colour, and somewhat firm tissue. They are situate anterior to the prostate; parallel to each other, and at the sides of the urethra. Each has an excretory duct, which creeps obliquely in the spongy tissue of the bulb, and opens before the verumontanum.

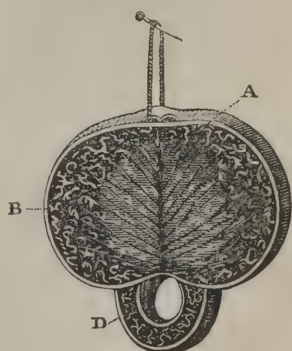
[1] Magendie, Précis, &c., ii. 514.

[2] E. H. Weber, Müller's Archiv., S. 421, Jahrgang, 1846: and Rud. Leuckart, art. Vesicula Prostatica, in Cyclop. of Anat. and Physiol., iv. 1415, Lond., 1852.

[3] S. R. Pittard, Art. Vesiculæ Seminales, Ibid., iv. 1429.

The *male organ* or *penis* consists of the *corpora cavernosa* and *corpus spongiosum;* parts essentially formed of an erectile tissue, and surrounded by a very firm elastic covering, which prevents over-distension, and gives form to the organ. The *corpora cavernosa* constitute the great body of the penis. They are two tubes, which are united and separated by an imperfect partition. Within them a kind of cellular tissue exists, into which blood is poured, so as to cause erection. The posterior extremities of these cavernous tubes are called *crura penis.* These separate in the perineum, each taking hold of the ramus of the pubis; and, at the other extremity, the cavernous bodies terminate in rounded points under the glans penis. The anatomical elements of the internal tissue of the corpora cavernosa are,—ramifications of the *cavernous artery*, which proceeds from the internal pudic; those of a vein bearing the same name; and probably, nerves,—although they have not been traced so far. All these elements are supported by filamentous prolongations from the outer dense envelope. A difference of opinion prevails amongst anatomists with regard to the precise arrangement of these prolongations. Some consider them to form cells, or a kind of spongy structure, on the plates of which the ramifications of the cavernous artery and vein and of the nerves terminate, and into which the blood is extravasated. Others conceive, that the internal arrangement consists of a plexus of minute arteries and veins, supported by the plates of the outer membrane, interlacing like the capillary vessels, but with this addition, that in place of the minute veins becoming capillary in the plexus, they are of greater size, forming very extensible dilatations and net-works, and anastomosing freely with each other. If the cavernous artery be injected, the matter first fills the ramifications of the artery, then the venous plexuses of the cavernous bodies, and ultimately returns by the cavernous vein, having produced erection. The same effect is caused still more readily by injecting the cavernous vein. Professor J. Müller, who has investigated the structure of the male organ, discovered two sets of arteries in the organ, differing from each other in size, mode of termination, and uses: the first he calls *rami nutritii*, which are distributed upon the parietes of the veins and throughout the spongy substance, differing in no respect from the nutritive arteries of other parts. The second set he calls *arteriæ helicinæ.* They differ from the nutritive vessels in form, size, and distribution. They are short, and are given off from the larger branches, as well as from the finest twigs of the artery; most of them come off at a right angle, and project into the cavity of the spongy substance, either terminating abruptly or swelling out into a clublike process without again subdividing. Almost all these arteries have this character, that they are bent like a horn, so that the end describes half a circle or somewhat more.

Fig. 404.

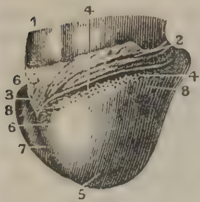


Section of the Penis.

A. External membrane or sheath of penis. B. Corpus cavernosum. D. Corpus spongiosum urethræ.

These arteries have a great resemblance to the tendrils of the vine, whence their name—*arteriæ helicinæ.* A minute examination of them, either with the lens or with the microscope, shows, that, although they at all times project into the venous cavities of the corpora cavernosa, as in the subjoined figures, they are not entirely naked, but are covered by a delicate membrane, which under the microscope appears granular. The views of Müller are embraced by Erdl, Krause, and Hyrtl,[1] but the researches of Valentin[2] and Berres, of Sappey, J. Béclard, Ch. Robin and Segond,[3] are not in accordance with them. The result of numerous examinations has convinced the former, that the helicine arteries are not peculiar vessels, but merely minute fibres that have been divided or torn; and that the real distribution of the vessels of the corpora cavernosa follows in every respect the most simple laws. Gerlach and Kölliker regard them as true vascular formations not produced artificially. They consider them not to be cæcal at their extremities, except in rare instances.[4] Kölliker[5] states, that he has observed them giving off minute vessels, which, like the other arterial prolongations, are continued further, and terminate in the venous spaces.

Fig. 405.



Glans Penis injected.

1, 1. Portions of corpora cavernosa. 2. Prepuce turned back. 3. Its frænum. 4, 4. Glandulæ odoriferæ Tysoni. 5. Point of glans. 6. Prominences of glans on each side of frænum. 7. Furrow which separates the sides of the glans. 8. Corona glandis.

The investigations of Müller led him to infer, that, both in man and the horse, the nerves of the corpora cavernosa are made up of branches proceeding from the organic as well as the ani-

Fig. 406.

Portion of the Erectile Tissue of the Corpus Cavernosum magnified, to show the areolar structure and the distribution of the arteries.

a. A small artery, supported by the larger trabeculæ, and branching out on all sides. *c.* The tendril-like arterial tufts, or helicine arteries of Müller. *d.* The areolar structure formed by the finer trabeculæ.

Fig. 407.

A single Tuft or Helicine Artery projecting into a Vein highly magnified.

[1] Lehrbuch der Anatomie des Menschen, S. 505, Prag., 1846.

[2] Müller's Archiv. für Anatomie, u. s. w., cited in Lond. Med. Gazette, June 23. 1838, p. 543; and Valentin, Lehrbuch der Physiologie des Menschen, ii. 843, Braunschweig, 1844.

[3] Traité d'Anatomie Générale, p. 314, Paris, 1854.

[4] J. W. Ogle, Report of Micrology, Brit. and For. Med. Chir.-Rev., Oct., 1855, p. 515.

[5] Mikroskopische Anatomie, ii. 412, Leipz., 1854, and Amer. edit. of Sydenham Society's edit. of his Human Histology, p. 632, Philad., 1854.

mal system, whilst the nerves of animal life alone furnish the nerves of sensation of the penis.

Attached to the corpora cavernosa, and running in the groove beneath them, is a spongy body of similar structure,—*corpus spongiosum urethræ*,—through which the urethra passes. It commences, posteriorly, at the bulb of the urethra,—already described under the Secretion of Urine,—and terminates anteriorly in the *glans*, which is, in no wise, a dependency of the corpora cavernosa, but is separated from them by a portion of their outer membranes; so that erection may take place in the one, and not simultaneously in the other; and injections into the corpora cavernosa of the one do not pass into those of the other. The glans appears to be the final expansion of the erectile tissue which surrounds the urethra. The posterior circular margin of the glans is called *corona glandis*, and behind this is a depression termed *cervix*, *collum* or *neck*. Several follicles exist here, called *glandulæ odoriferæ Tysoni:* these have always been considered to secrete an unctuous humour called *smegma præputii*, which often accumulates largely, where cleanliness is not attended to. The little white elevations that are found around the corona glandis have been generally regarded as Tyson's glands. They have, however, been examined by Dr. G. Simon,[1] who affirms, that they are nothing more than small round elevations of cutis, covered by papillæ and epithelium. They consist of fibro-areolar tissue, like that of the rest of the cutis; and the papillæ on them have no peculiar characters. The sole function which he ascribes to them is that of increasing the sensibility of the glans. The only organs, which Dr. Simon could find for the special secretion of the smegma—and these are not constant—are whitish corpuscles lying in or beneath the cutis, which, with the microscope, appear as small roundish sacculi, closed below, opening by a narrow orifice on the surface, and containing a white substance. These are usually situate on or behind the corona glandis, in front of or near the frænum, and sometimes on the anterior surface of the glans. Two or three may be found, and, in a few cases, as many as six.

The penis is covered by the skin, which forms, towards the glans, the *prepuce* or *foreskin*. The areolar tissue which unites it to the organ is lax, and never contains fat. The inner lamina of the prepuce being inserted circularly into the penis, some distance back from the point, the glans can generally be denuded, when the prepuce is drawn back. The under and middle part of the prepuce is attached to the extremity of the glans by a duplicature, called *frænum præputii*, which extends to the orifice of the urethra. The skin is continued over the glans, but it is greatly modified in its structure, being smooth and velvety, highly delicate, sensible, and vascular.

Lastly.—In addition to the *acceleratores urinæ*, *transversus perinei*, *sphincter ani*, and *levator ani* muscles, which we have described as equally concerned in the excretion of urine and semen, the *erector penis* or *ischio-cavernosus* muscle is largely connected with the function of

[1] Müller's Archiv., 1844, Heft 1, cited in Brit. and For. Med. Rev., April, 1845, p. 567.

generation. (See Fig. 181.) The genital organs of man are, in reality, merely an apparatus for a glandular secretion, of which the testicle is the gland; the vesiculæ seminales are supposed to be the reservoirs; and the vas deferens and urethra the excretory ducts;—the arrangement which we observe in the penis being for the purpose of conveying the secreted fluid into the parts of the female.[1]

1. SPERM.

The sperm is secreted by the testicles from the blood of the spermatic artery, by a mechanism, which is no more understood than that of secretion in general. When formed, it is received into the tubuli seminiferi, and passes along them to the epididymis, vas deferens, and vesiculæ seminales, where it is generally conceived to be deposited, until under venereal excitement it is projected into the urethra. That this is its course is sufficiently evidenced by the arrangement of the excretory ducts, and by the function which it has to fulfil. De Graaf,[2] however, adduces an additional proof. On tying the vas deferens of a dog, the testicle became swollen under excitement, and ultimately the duct gave way between the testicle and ligature. The causes of the progression of the sperm through the ducts are,—the continuity of the secretion by the testicle, and the contraction of the excretory ducts themselves. These are the efficient agencies.

It has been a question with physiologists, whether the secretion of the sperm be constantly taking place—or whether, as the function of generation is accomplished at uncertain intervals, the secretion may not likewise be intermittent. It is impossible to arrive at any positive conclusion on this point. It would seem, however, unnecessary for the secretion to be effected at all times; and it is more probable, that when the vesiculæ seminales are emptied of their contents during coition, a stimulus is given to the testes by the excitement, and they are soon replenished. This, however, becomes more and more difficult in proportion to the number of repetitions of the venereal act, as the secretion takes place at best but slowly. By some, the spermatic and pampiniform plexuses have been regarded as diverticula to the testes during this intermission of action. The sperm passes slowly along the excretory ducts of the testicle, owing partly to the slowness of the secretion, and partly to the arrangement of the ducts, which, as we have seen, are remarkably convoluted, long, and minute. The use of the vesiculæ seminales has been disputed. The majority of physiologists consider them to be reservoirs for the sperm, and to serve the same purpose as the gall-bladder in the case of the bile. Others, however, have supposed, that they secrete a fluid of a peculiar nature, the use of which may probably be to dilute the sperm; whilst others, again, infer, that they are both seminal reservoirs, and secreting organs,—furnishing mucus, or some other fluid, for admixture with the semen. Dr. John Davy[3] found spermatozoids in the fluid of the

[1] See Kobelt, De l'Appareil du Sens Génital des deux Sexes, traduit de l'Allemand, par H. Kaula, D. M. Paris, 1851.

[2] De Virorum Organ. Gener. inserv., in Med. Oper. Omn., Amstel., 1705.

[3] Edinb. Med. and Surg. Journ. for July, 1838, p. 12; and Researches, Physiological and Anatomical, Amer. Med. Libr. edit., p. 363, Philad., 1840.

vesiculæ; but except in two instances none could be seen in that expressed from the divided substance of the testes. He invariably observed, however, extremely minute, dense spherules, which he conjectured to be ova of spermatozoids.[1] The vesiculæ are manifestly not essential to the function of generation, as they do not exist in all animals; and in several animals in which they do, there is no direct communication between the duct and the vas deferens, which open separately into the urethra. This circumstance, however, with the fact, that they generally contain, after death, a fluid of different appearance and properties from those of the sperm,—with the glandular structure, which their coats seem in many instances to possess,—is opposed to the view, that they are simple reservoirs for semen, and favours that which ascribes to them a peculiar secretion. Where this communication between the duct of the vesiculæ and the vas deferens exists, a reflux of the semen and an admixture between the sperm and the fluid secreted by them may take place. It is not improbable, however, as M. Adelon[2] suggests, that all the excretory ducts of the testicle may act as a reservoir; and in the case of animals, in which the vesiculæ are wanting, they must possess this office exclusively. If we are to adopt the description of M. Amussat as an anatomical fact, the vesiculæ themselves are constituted of a convoluted tube, having an arrangement somewhat resembling that which prevails in the excretory ducts of the testes.[3]

That these excretory ducts may serve as reservoirs is proved by the fact, that impregnation is practicable after thorough castration. This has been doubted both as regards animals and man, but there is no question of the fact as respects the former. Dr. Pue, of Baltimore, related to the author unquestionable instances of the kind. In one case, a boar was observed on one side of a hedge striving to get at some sows in heat on the other side. The boar was castrated, and no inconvenience being apprehended, he was turned loose into the field with the sows. In five minutes after the operation, he had intercourse with one of them, and subsequently with others. The first sow brought forth a litter, but none of the others were impregnated. In another case, after a horse had been castrated, it was recollected, that the male organ had not been washed—which, it seems, is looked upon as advisable. To save inconvenience, it was suggested, that the same effect might be produced by putting him to a mare, then in the stable, and in heat. This was done, and, in due time, the mare brought forth a foal, unequivocally the result of this sexual union. Mr. Walton Hamilton,—a great breeder of horses, in Saratoga county, New York,—informed the author's friend, Mr. Nicholas P. Trist, that he, also, had known several instances of impregnation after castration.[4]

It is to be presumed, that the power of procreation can exist for a short time only after the operation; yet a secretion may take place from the lining membrane of the ducts, and vesiculæ, and from the

[1] Researches, Physiological and Anatomical, Amer. Med. Libr. edit., p. 373, Philad., 1840.

[2] Physiologie de l'Homme, 2de édit., iv. 15, Paris, 1829.

[3] Magendie, Précis, &c., ii. 348.

[4] See some remarks, by the author, in American Medical Intelligencer, p. 146, July 15, 1837; and by Dr. Warrington, Ibid., p. 244, Oct. 1.

prostate and other follicles; but this secretion cannot supply the place of sperm. Sir A. Cooper gives the case of a man, who stated to him, that for nearly the first twelve months after complete castration, he had emissions in *coitu*, or the sensation of emissions. Afterwards, he had erections and intercourse at distant intervals, but without the sensation of emission.[1]

It has been asked, how it happens, that the sperm, in its progress along the vas deferens, does not pass directly on into the urethra by the ejaculatory duct, instead of reflowing into the spermatic vesicles where these exist? This, it has been imagined, is owing to the existence of an arrangement at the opening of the ejaculatory duct into the urethra, similar to that which prevails at the termination of the choledoch duct in the duodenum. It is affirmed by some, that the prostate exerts a pressure on the ductus ejaculatorius, and that the opening of the duct into the urethra is smaller than any other part of it; by others, that the ejaculatory ducts are embraced, along with the neck of the bladder, by the levator ani, and consequently, that the sperm finds a readier access into the ducts of the vesiculæ.

Sperm—*sperma*, *semen*, *lac maris*, *male's milk*, *propagatory* or *genital liquor*, *vitale virus*, *vital* or *quickening venom*—is of a white colour, and of a faint smell, which, owing to its peculiar character, has been termed *spermatic*. This smell would seem to be derived from the secretions of the vesiculæ seminales, prostate, and mucous follicles of the urethra, as pure semen taken from the epididymis or vas deferens does not possess it. It is of viscid consistence, a saline, irritating taste, and appears composed of two parts, the one more liquid and transparent, and the other more grumous. In a short time after emission, these two parts unite, and the whole becomes more fluid. When examined chemically, sperm appears to be of an alkaline and albuminous character. M. Vauquelin[2] analyzed it, and found it to be composed,—in 1000 parts,—of water, 900; animal mucilage, 60; soda, 10; calcareous phosphate, 30. John's analysis[3] accords with this. Berzelius affirms, that it contains the same salts as the blood, along with a peculiar animal matter—*spermatin*. After citing these analyses, M. Raspail[4] observes, that if any thing be capable of humiliating the pride of the chemist, it is assuredly the identity he is condemned to discover amongst substances, which fulfil such different functions. Of late, the sperm of the carp, the cock, and the rabbit has been subjected to repeated and careful analysis by Professor Frerichs of Göttingen; and the following are the published results. *First*. The pure semen presents the appearance of a milky fluid, of a mucous consistence and neutral reaction. A slight alkaline reaction was perceived only once. *Secondly*. The developed spermatozoids consist of binoxide of protein; the same substance, which Mulder has proved to be the principal constituent of the epithelia, as well as of the horny tissues in general. *Thirdly*. The spermatozoids contain about 4 per cent. of a butter-like fat, as well as phosphorus in an unoxidized

[1] Observations on the Structure and Diseases of the Testis, Lond., 1830.

[2] Annales de Chimie, ix. 64.

[3] Chemische Tabellen des Thierreichs, S. 169, Nürnberg, 1814; cited in Burdach's Physiologie, u. s. w., S. 111.

[4] Chimie Organique, p. 386, Paris, 1833.

state, and about 5 per cent. of phosphate of lime. *Fourthly.* The fluid part is a thin solution of mucus, which, in addition to the animal matter, contains chloride of sodium and small quantities of phosphate and sulphate of the alkalies. *Fifthly.* The imperfectly developed spermatozoids are composed of an albuminous substance, the quantity of which diminishes in proportion to the progress of the morphological developement. *Sixthly.* The perfectly developed semen contains no longer any albuminous compound; and *Seventhly.* The semen in fishes, birds, and the mammalia possesses, essentially, the same chemical composition.

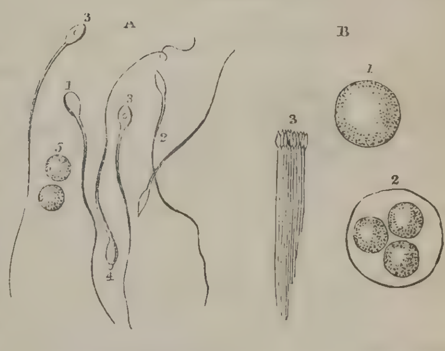
The most important inference deducible from these statements communicated by Professor Frerichs to Messrs. Wagner and Leuckardt,[1] is, according to these gentlemen, the fact, that the spermatozoids, in their chemical constitution, belong to the same category as the epithelial cells of the animal body, which, they think, removes every doubt respecting the nature of these formations,—every idea, that is, of their being independent animals. That they are not so appears to the author most probable, but not for the chemical reasons given by these gentlemen, whose conclusion can scarcely, indeed, be regarded in any other light than as a *non sequitur.*

No analysis has been made of the sperm as secreted by the testicle. The fluid examined has been the compound of it and the secretions of the prostate gland and those of Cowper. The thicker, whitish portion is considered to be the secretion of the testicles;—the more liquid and transparent, the fluids of the accessory glands or follicles.

Some authors have imagined, that a sort of halitus or aura is given off from the sperm, which they have called *aura seminis*, and have considered to be sufficient for fecundation. The fallacy of this view will be exhibited hereafter.

By the microscope, numerous minute bodies, already referred to, are seen in the sperm, termed *seminal animalcules*, *spermatozoa*, *zoospermes*, *spermatozoids* or *seminal* or *spermatic filaments* — which have generally been conceived important agents in generation. By careful examination, Wagner[2] discovered other minute, round, granulated bodies which may almost always be detected; and are much less numerous than the spermatozoids. These bodies he distinguishes by the name *seminal*

Fig. 408.



Spermatozoa from Man, and their developement.

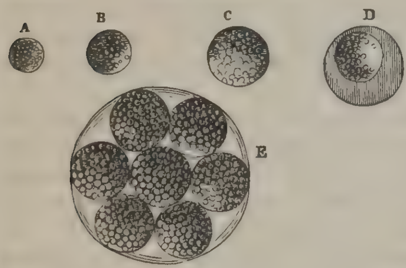
A. Spermatozoa from the semen of the vas deferens. 1 to 4. Show their variety of character. 5. Seminal granules.—B. Contents of the semen of the testis. 1. Large round corpuscle or cell. 2. A cell containing three roundish granular bodies, from which the spermatozoa are developed. 3. A fasciculus of spermatozoa, as they are seen grouped together in the testis.

[1] Art. Semen, Cyclop. of Anat. and Physiol., Pt. xxxiv. p. 506, January, 1849; and art. Zeugung, in Wagner's Handwörterbuch der Physiologie, iv. 849, Braunschw., 1853.

[2] Elements of Physiology, translated from the German, by Robert Willis, M. D., pt. i. p. 4, Lond., 1841; see, also, Mandl, Manuel d'Anatomie Générale, p. 494, Paris, 1843.

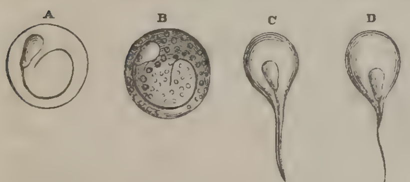
granules, *granula seminis*. Both elements of the sperm are suspended in a small quantity of fluid perfectly homogeneous, transparent, and clear as water. "Pure semen, therefore, in its most perfect state, consists principally of *seminal animalcules* and *seminal granules*, both of which are enveloped in a small quantity of fluid." This fluid Wagner called *liquor seminis;* and he suggested,[1] in connexion with the discoveries of Schwann and Schleiden, (referred to at page 463 of the first volume,) whether, in the developement of the spermatozoids, the liquor seminis may not be regarded as a matrix (Zellenkeimstoff, *cytoblastema*, Schwann), in which the granular nuclei are developed as *cytoblasts*, which again put forth their covering or cyst as a cellular wall. The finely granular contents would then have to be considered as the *cell-fluid*. The cytoblasts disappear as soon as the spermatozoids are evolved in their contents; and the cells burst and cast out the fancied animalcules, as the cells of the algæ scatter abroad their sporules. More recently, Wagner, in conjunction with Leuckardt, has published the results of his farther observations and of those of others on this matter. Among the mammalia, they affirm, the developement of spermatozoids takes place in the interior of vesicle-shaped globules, which fill up the minute ducts of the testicles in great quantity. Most of these vesicles, "vesicles of evolution," are free within the ducts, as represented in the marginal figures, A, B, C, Fig. 409; and are frequently surrounded by a membrane, either singly, as in D, or in numbers of from three to seven, E; and, according to Kölliker, one cyst may contain as many as twenty. All these cells of evolution or developement are formed within other cells; and it is often difficult to determine, whether an individual cell or vesicle is destined for the production of other cells—daughter cells—or immediately for the formation of a spermatozoid. Wherever free vesicles of developement are found, they have—in the opinion of Wagner and Leuckardt[2]—been produced in the interior of other cellular formations, and have been set free by their dissolution. Each spermatozoid would seem to be produced in a separate cyst, and where many of these are seen in one cyst, it is owing to the different vesicles having burst and discharged their spermatozoids into the external cyst. The number of enclosed sperm-

Fig. 409.



Developing Vesicles of Spermatozoids from the Testicle of the Dog.

Fig. 410.



Spermatozoid of the Dog in the Interior of the Vesicle of Developement.

[1] Op. cit., p. 27.

[2] Op. cit., p. 477.

atozoids will thus be an index of the number of vesicles of developement. A, B, C, D, Fig. 410, exhibit the mode in which the spermatozoid lies in the vesicle of developement; and in which it is occasionally seen projecting from it.

Great difference of sentiment has existed in regard to the nature of those bodies. M. Virey[1] conceives, that as the pollen of vegetables is a collection of small capsules, containing within them the true fecundating principle, which is of extreme subtilty, the pretended spermatic animalcules are tubes containing the true sperm, and the motion we observe in them is owing to the rupture of the tubes; whilst M. Raspail[2] is led to think, that they are mere shreds, (*lambeaux*,) of the tissues of the generative organs, ejaculated with the sperm, which describe involuntary movements by virtue of the property they possess of *aspiring* and *expiring*. In confirmation of this view, he states, that if we open an ovary of the mussel, we may observe alongside the large ovules myriads of moving shreds, whose form and size are infinitely varied, and which possess nothing resembling regular organization. They bear evident marks of laceration. These shreds, he conceives, may affect greater regularity in certain classes of animals of a more elevated order; but he concludes, that howsoever this may be, the spermatic animalcules, which have hitherto been classed amongst those *incertæ sedis*, may be provisionally placed in the genus *cercaria*,—that is, amongst infusory, agastric animals having a kind of tail,—which M. Raspail considers the simplest of animated beings, and to live only by "aspiration and expiration." Wagner also remarks, that the expression *cercaria seminis*, applied to spermatozoids, can only be a collective title, and that the manifold forms of spermatozoids, which he has found in the seminal fluid of a great number of animals, must be viewed in the light of so many different species. Ehrenberg refers them to the haustellate entozoa.

The author has repeatedly examined the sperm with microscopes of high magnifying power, but without being able to satisfy himself, that the minute caudate bodies, contained in it, are animalcular. Sir Everard Home[3] and Mr. Bauer were equally unsuccessful, and they were led to conclude, that the appearance of living animalcules in the semen is not real, but the effect of a microscopic deception. Wagner[4] formerly considered, that they are essential elements of the seminal fluid, and bear a specific relation to the generative act, and that they are thus far comparable to the blood-globules, which present themselves in the same manner, as essential typically organized constituents of the blood amid the liquor sanguinis, just as the spermatozoids present themselves amid the liquor seminis. The question of the animality of these spermatozoids he considered to be undetermined, as their internal organization had not been detected. In the appendix, however, to the translation of his work, Dr. Willis[5] remarks, that in the examination of the spermatozoids of the bear, Valentin[6] had set-

[1] Art. Génération, in Dict. des Sciences Médicales; and Philosophie d'Histoire Naturelle, Paris, 1835.
[2] Op. citat., p. 389.
[3] Lect. on Comp. Anat., v. 337, Lond., 1828.
[4] Op. citat., p. 34.
[5] Ibid., p. 228.
[6] Nov. Act. Acad. C. L. Natur. Curios., vol. xi. 1839.

tled the question of the organization, and consequently true animal nature, of the seminal animalcule; but the matter was not determined by this statement, nor by the categorical declaration of M. Pouchet,[1] that "every mode of investigation presented to the human mind appears to speak in favour of the animality of the spermatozoids. Inward feeling (*le sens interne*), observation, experiment, and reflection, unite in expressing, that they can be nothing else than animals." On the other hand, M. Donné,[2] like M. Raspail, regards them as resulting from a kind of desquamation of the parietes of the seminiferous tubes; whilst Carpenter,[3] Dujardin,[4] and others consider, that there is little reason to regard them as independent animalcules. The former esteems them to be bodies having an inherent power of motion, not exceeding in their activity ciliated epithelium cells, and even blood corpuscles; and he thinks there is no evidence, that their function is any higher than that of the pollen-tube of plants, which conveys into the ovulum the germ of the first cells of the embryo. The whole of this subject has been since re-examined by Wagner in connexion with Leuckardt; and in an able view by these gentlemen,[5] of the morphology and developement of the spermatozoids, we have the following remarks:—"At the period when the spermatozoa were still considered as individual animated creatures, it was natural, that those qualities should be sought for, which distinguish animals generally; and it was frequently asserted, that the distinct traces of an internal organization had been found in them. Even Leeuwenhoek,[6] the oldest observer of these structures, describes in the body of the spermatozoa of the ram and of the rabbit indications, which were subsequently interpreted by Ehrenberg[7] and Valentin[8] to be intestines, stomachic vesicles, and even generative organs. Other histologists,—for instance, Schwann and Henle,—thought themselves justified in calling a dark spot, which shows itself occasionally on the body of the spermatozoon in man, but which is decidedly a mere accidental formation, as a suctorial cavity. But all these statements are now no longer believed in, as our present knowledge of the developement of these formations has entirely removed the idea of their parasitic nature. Indeed, the subject requires no further refutation, as an unprejudiced observation proves that the spermatozoa are everywhere void of a special organization, and consist of a uniform homogeneous substance, which exhibits, when examined by the microscope, a yellow amber-like glitter. The abovementioned investigators have by this time undoubtedly seen their error."

The view, that they are reproductive particles, but not animalcules, appears to the author to be the most in accordance with the phenomena.

[1] Théorie Positive de l'Ovulation Spontanée, et de la Fécondation, &c., p. 363, Paris, 1847.

[2] Cours de Microscopie, p. 176, Paris, 1844.

[3] Human Physiology, § 733, Lond., 1842; also, Amer. edit., p. 750, Philad., 1855.

[4] Annales des Sciences Natur. Zoologie, viii. 291; and Manuel de l'Observateur au Microscope, p. 96, Paris, 1843.

[5] Art. Semen, in Cyclop. of Anat. and Physiology, part xxxiv. p. 502, Jan., 1849.

[6] Opera, iv. 168, 284.

[7] Infusoriensthierchen, S. 465.

[8] Nov. Act. Acad. Leopold, xix. 239.

The presence of spermatozoids, whole or broken in fragments, may aid in detecting nocturnal emissions, and be of assistance in cases of alleged rape. It would seem, however, that they are not found solely in the sperm: for Mr. Liston and Mr. Lloyd,[1] of St. Bartholomew's Hospital, London, stated to the Medico-Chirurgical Society, that in cases of common hydrocele, in which they examined microscopically the fluid withdrawn by tapping, they found a great number of them. Mr. Lloyd counted forty in one drop. Some were observed to retain their power of motion for three hours after the fluid had been withdrawn. In the fluid of many other cases of hydrocele, he was unable to detect them. Since these remarks were made, however, by Mr. Lloyd, they have been observed repeatedly in the fluid of common hydrocele of the tunica vaginalis testis, and in encysted hydroceles.[2] This may be owing to the rupture of a seminal duct; but Mr. Paget[3] considers, that the most probable explanation of their occurrence in the fluid of cysts connected with the testicle seems to be, that certain cysts, seated near the organ which naturally secretes the materials for semen, may possess the power of forming a similar fluid. It must be borne in mind, however, as before remarked, that bodies resembling spermatozoids were found by M. Donné in the nasal mucus.

The agency of the sperm in fecundation will be considered hereafter.

The sperm being the great vivifying agent,—the medium by which life is communicated from generation to generation,—it has been looked upon as one of the most—if not the most—important of animal fluids: and hence it is regarded, by some physiologists, as formed of the most animalized materials, or of those that constitute the most elevated part of the new being—the nervous system. The quantity of sperm secreted cannot be estimated. It varies according to the individual, and to his extent of voluptuous excitement, as well as to the degree of previous indulgence in venereal pleasures. Where the demand is frequent, the supply is larger; although when the act is repeatedly performed, the absolute quantity at each copulation may be less.[4]

b. *Genital Organs of the Female.*

The genital organs of the male effect fewer functions than those of the female. They are inservient to copulation and fecundation only. Those of the female,—in addition to parts, which fulfil these offices,—comprise others for gestation and lactation.

The soft and prominent covering to the symphysis pubis—which is formed by the common integument, elevated by fat, and, at the age of puberty, covered by hair, formerly termed *tressoria*—is called *mons*

[1] Provincial Medical Journal, cited in Medical Examiner, July 22, 1843, p. 168.

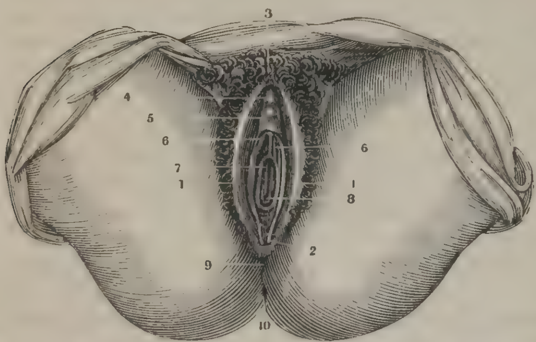
[2] Medico-Chirurgical Transactions, vol. xxvii., Art. 25, London, 1844; Dr. R. L. Macdonnell, British American Journal of Medicine, Montreal, 1849; and Mr. Curling, Edinb. Monthly Journal of Med. Science, May, 1843; and Art. Testicle, in Cyclop. of Anat. and Physiol., Pt. xxxviii. p. 998, Feb. 1850.

[3] Brit. and For. Med. Rev., January, 1844, p. 270.

[4] Theophrastus, Pliny, and Athenæus assert, that with the help of a certain herb, an Indian prince was able to copulate seventy times in twenty-four hours!—Theophr. l. c. v., Plin. l. xxvi. c. 9, and Athenæus, l. i. c. 12. See, also, Art. Cas rares, in Dict. des Sciences Médicales.

veneris. The absence of this hair has, by the vulgar, been esteemed a matter of reproach; and it was formerly the custom, when a female had been detected a third time in incontinent practices, in the vicinity of the Superior Courts of Westminster, to punish the offence by cutting off the tressoria[1] in open court. Occasionally its growth is excessive. Below this are the *labia pudendi* or *labia majora*, which are two large, soft lips, formed by a duplicature of the common integument, with adipose matter interposed. The inner surface is smooth, and studded with sebaceous follicles. The labia commence at the symphysis pubis, descend to the *perinæum*, which is the portion of integument, about an inch and a half in length, between the posterior commissure of the labia and the anus. This commissure is called *frænum labiorum*, *frænulum perinei* or *fourchette.* The opening between the labia is the *vulva* or *fossa magna.* At the upper junction of the labia and within them, a small organ exists, called *clitoris* or *superlabia*, which greatly resembles the penis. It is formed of corpora cavernosa, and is terminated anteriorly by the *glans*, which is covered by a prepuce consisting of a prolongation of the mucous membrane of the vagina. Unlike the penis, however, it has no corpus spongiosum or urethra attached to it; but is capable of being made erect by a mechanism similar to that which exists in the penis; and it has two erector muscles, the *erectores clitoridis*, similar to the erectores penis. Anciently, if a female was detected a fourth time in incontinence in the vicinity of the Superior Courts of Westminster, the clitoris was amputated in open court.[2] Extending from the prepuce of the clitoris, and within the labia majora, are the *labia minora* or *nymphæ*, the organization of which is similar to that of the labia majora. They gradually enlarge as they pass downwards, and disappear when they reach the orifice of the vagina.

Fig. 411.



External Organs of Generation in the Unmarried Female—the Vulva being partially opened.

1, 1. Labia majora. 2. Fourchette. 3. Mons veneris. 4. Præputium clitoridis around glans clitoridis. 5. Vestibulum. 6. Nymphæ. 7. Meatus urinarius. 8. Hymen, open in its central portion and surrounding inferior extremity of the vagina. 9. Perineum. 10. Anus.

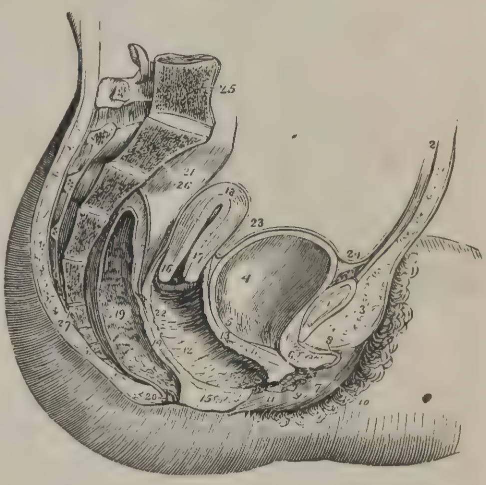
A singular variety is observed in the organization of those parts amongst the Bosjesmen or Bushmen, a tribe to whose peculiarities of organization we have already had occasion to refer. Discordance has, however, prevailed regarding the precise nature of this peculiarity,—some describing it as existing in the labia; others in the nymphæ, and

[1] Chitty's Practical Treatise on Medical Jurisprudence, Pt. i. p. 390, American edit., Philad., 1836.

[2] Chitty, op. cit., Pt. i. p. 391, Amer. edit., Philad., 1836.

others again, in a peculiar organization; some, again, deeming it natural, others artificial. Dr. Somerville,[1] who had numerous opportunities for observation and dissection, asserts, that the mons veneris is less prominent than in the European, and is either destitute of hair, or thinly covered by a small quantity of a soft, woolly nature; that the labia are very small, so that they seem at times to be almost wanting; that the loose, pendulous, and rugous growth, which hangs from the pudendum, is a double fold; and that it is proved to be the nymphæ, by the situation of the clitoris at the commissure of the folds, as well as by all other circumstances; and that they sometimes reach five inches below the margin of the labia: Le Vaillant[2] says nine inches. Cuvier[3] examined the Hottentot Venus, and found her to agree well with the account of Dr. Somerville. The labia were very small; and a single prominence descended between them from the upper part. It divided into two lateral portions, which passed along the sides of the vagina to the inferior angle of the labia. The whole length was about four inches. When she was examined naked by the French *Savans*, this formation was not observed. She kept the *tablier*, *ventrale cutaneum*, or, as it is termed by the Germans, Schürze ("apron,") carefully concealed, either between her thighs, or yet more deeply; and it was not known, until after her death, that she possessed it. Both Sir John Barrow[4] and Dr. Somerville deny, that the peculiarity is induced artificially.

Fig. 412.



Side View of Viscera of Female Pelvis.

1. Symphysis pubis. 2. Abdominal parietes. 3. Fat forming the mons veneris. 4. Bladder. 5. Entrance of left ureter. 6. Canal of urethra. 7. Meatus urinarius. 8. Clitoris and its prepuce. 9. Left nympha. 10. Left labium majus. 11. Orifice of vagina. 12. Its canal and transverse rugæ. 13. Vesico-vaginal septum. 14. Vagino-rectal septum. 15. Section of perineum. 16. Os uteri. 17. Cervix uteri. 18. Fundus uteri. 19. Rectum. 20. Anus. 21. Upper portion of rectum. 22. Recto-uterine fold of peritoneum. 23. Utero-vesical reflection of peritoneum. 24. Peritoneum reflected on the bladder from abdominal parietes. 25. Last lumbar vertebræ. 26. Sacrum. 27. Coccyx.

In warm climates, the nymphæ are often greatly and inconveniently elongated, and amongst the Egyptians and other African tribes, it has been the custom to extirpate them, or diminish their size. This is what is meant by *circumcision* in the female.

The *vagina* is a canal, which extends between the vulva and uterus, the neck of which it em-

[1] Medico-Chirurgical Transactions, vii. 157.

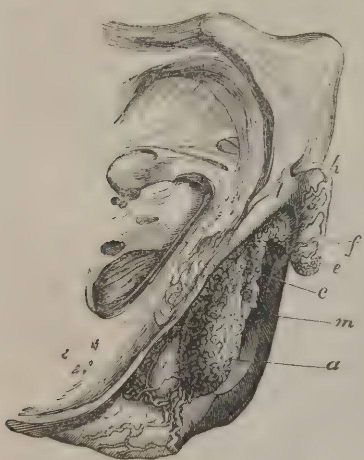
[2] Voyage dans l'Intérieur d'Afrique, p. 371.

[3] Mémoir. du Muséum, iii. 266; and Broc, Essai sur les Races Humaines, p. 87, Paris, 1835.

[4] Travels into the interior of Southern Africa, p. 279; also, Lawrence's Lectures on Comparative Anatomy, Physiology, Zoology, &c., 9th edit., p. 289, Lond., 1844.

braces. It is sometimes called *vulvo-uterine canal*, and is from four to six inches long, and an inch and a half, or two inches, in diameter. It is situate in the pelvis, between the bladder before, and the rectum behind; is slightly curved, with the concavity forwards, and narrower at the middle than at the extremities. Its inner surface has numerous —chiefly transverse—rugæ, which become less in the progress of age, after repeated acts of copulation, and especially after accouchement. It is composed of an internal mucous membrane, supplied with numerous follicles, of a dense areolar membrane; and, between these, a layer of erectile tissue, which is thicker near the vulva; but is, by some, said to extend even as far as the uterus. It is termed the *corpus spongiosum vaginæ*. It is chiefly situate around the anterior extremity of the vagina, below the clitoris, and at the base of the nymphæ; and the veins of which it is constituted are called *plexus retiformis*. The upper portion of the vagina, to a small extent, is covered by peritoneum. The *sphincter* or *constrictor vaginæ muscle* surrounds the orifice of the vagina, and covers the plexus retiformis. It is about an inch and a quarter wide, and ordinarily about six inches in length; arises from the body of the clitoris, and passes backwards and downwards, to be inserted into the dense, white substance in the centre of the perineum, which is common to the transversi perinei muscles, and the anterior point of the sphincter ani.

Fig. 413.



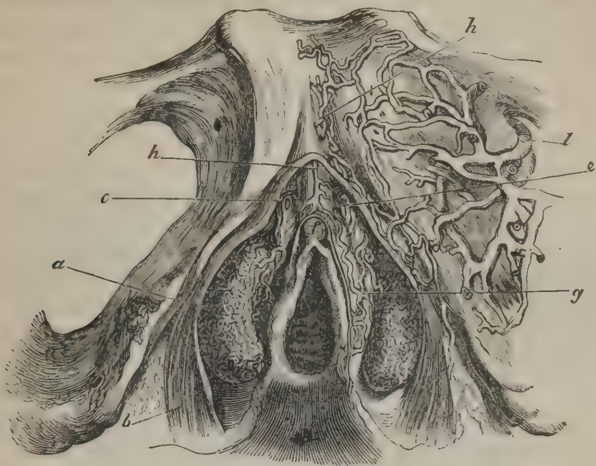
Lateral View of the Erectile Structures of the External Organs of Generation in the Female, the Skin and Mucous Membrane being removed.

a. Bulbus vestibuli. *c.* Plexus of veins named pars intermedia. *e.* Glans of the clitoris. *f.* Body of the clitoris. *h.* Dorsal vein. *l.* Right crus of clitoris. *m.* Vulva. *n.* Right gland of Bartholine.

Near the external aperture of the vagina is the *hymen* or *virginal* or *vaginal valve*, which is a more or less extensive, membranous duplicature, of variable shape, formed by the mucous membrane of the vulva, where it enters the vagina, so that it closes the canal more or less completely. It is generally very thin, and easily lacerable: but is sometimes extremely firm, so as to prevent penetration. It is usually of a semilunar shape; sometimes oval from right to left, or almost circular, with an aperture in the middle; whilst, occasionally, it is entirely imperforate, and of course prevents the issue of the menstrual flux. It is easily destroyed by mechanical violence of any kind, as by strongly rubbing the sexual organs of infants with coarse cloths, and by ulcerations of the part; hence its absence is not an absolute proof of the loss of virginity, as it was of old regarded by the Hebrews, nor is its presence a positive evidence of continence. Individuals have conceived, in whom the aperture of the hymen has been so small as to prevent penetration. Its general semilunar or crescentic shape has been considered to explain the origin of the symbol of the

crescent assigned to Diana, the goddess of chastity. Around the part of the vagina where the hymen was situate, small, reddish, flattened, or rounded tubercles—*carunculæ myrtiformes* seu *hymenales*—afterwards exist, which are of various sizes; and are formed, according to the

Fig. 414.



Front View of the Erectile Structures of the External Organs of Generation in the Female.

a. Bulbus vestibuli. *b*. Sphincter vaginæ muscle. *e, e*. Venous plexus, or pars intermedia. *f*. Glans of the clitoris. *g*. Connecting veins. *h*. Dorsal vein of the clitoris. *k*. Veins going beneath pubes. *l*. The obturator vein.

general opinion, by the remains of the hymen. MM. Béclard and J. Cloquet[1] consider them to be folds of mucous membrane. Their number varies from two to five, or six.

Fig. 415.

Anterior View of the Uterus and Appendages.

a. Fundus, *b*, body, and *c*, cervix or neck of the uterus. *e*. Front of the upper part of the vagina. *n, n*. Round ligaments of the uterus. *r, r*. Broad ligaments. *s, s*. Fallopian tubes. *t*. Fimbriated extremity. *u*. Ostium abdominale. The position of the ovaries is shown through the broad ligaments; and also the cut edge of the peritoneum, along the lower border of the broad ligaments and across the uterus.

[1] Dictionnaire de Médecine, &c., art. Caroncule, Paris, 1821.

At either side of the entrance of the vagina, beneath the integument covering its inferior part, as well as the superficial perineal fascia, and the constrictor vaginæ muscle, are situate the *glands of Duverney* or *of Bartholin*. The space they occupy lies between the lower end of the vagina, the ascending ramus of the ischium, the crus clitoridis, and the erector clitoridis muscle. The excretory duct is at the anterior edge of the superior part of the gland, and runs beneath the constrictor vaginæ, horizontally forwards and inwards, to the inner face of the nympha,

Fig. 416.

Posterior View of the Uterus and its Appendages: the Cavity of the Uterus being shown by the removal of its Posterior Wall; and the Vagina being laid open.

a. Fundus, *b*, body, and *c*. cervix of the uterus, laid open. The arbor vitæ is shown in the cervix. *d*. The os uteri externum, laid open. *e*. The interior of the upper part of the vagina. *f*. Section of the walls of the uterus. *i*. Opening into Fallopian tube. *o*. Ovary. *p*. Ligament of ovary. *r*. Broad ligament. *s*. Fallopian tube. *t*. Fimbriated extremity.

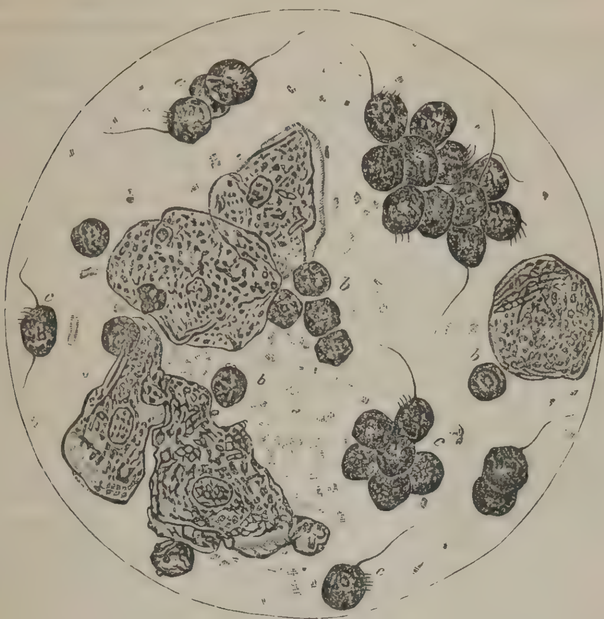
opening in front of the carunculæ myrtiformes in the midst of a number of small mucous follicles. These glands secrete a thick, tenacious, grayish-white fluid, which is emitted in considerable quantity towards the termination of sexual intercourse, and—it has been suggested—through the spasmodic contraction of the constrictor vaginæ muscle under which they lie.

When proper attention to cleanliness is not paid, so that the secretion from the mucous membrane of the vagina is no longer healthy, an animalcule—the *trichomonas vaginalis*—has been detected in it by M. Donné;[1] with occasionally small vibriones, which can only be seen when magnified three or four hundred times. (Fig. 417.) Donné, Dujardin, and Raspail regard it as an infusory animalcule; Froriep and Ehrenberg as a species of acarus; whilst Gluge, Lebert, Valentin, Siebold, Wagner, and Vogel[2] are of opinion, that it is not an animal, but ciliated epithelium separated from the uterus. Kölliker and Scanzoni[3] have,

[1] Cours de Microscopie, p. 157, Paris, 1844; and Atlas, Paris, 1845.
[2] The Pathological Anatomy of the Human Body, by Julius Vogel, translated, &c., by G. E. Day, p. 440, Lond., 1847.
[3] Gazette Hebdomadaire, Mai 18, 1855; and Edinb. Med. Journ., Oct., 1855, p. 367.

however, made it a subject of fresh research, and have discovered in it all the characters of the true infusoria, and such as closely resemble those described by M. Donné.

Fig. 417.



Vaginal Mucus containing Trichomonads, magnified 400 diameters.
***b, b, b.* Purulent globules. *c, c, c, c.* Trichomonads.**

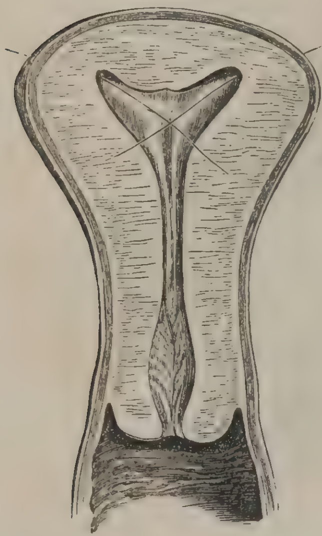
The vagina is at times double. Three such cases have been recorded by Professor Meigs.[1]

The *uterus* is a hollow organ for the reception of the fœtus, and its retention during gestation. It is situate in the pelvis, between the bladder—which is before, and the rectum behind, and below the convolutions of the small intestines. Fig. 412 gives a lateral view of their relative situation. It is of a conoidal shape, flattened on the anterior and posterior surfaces; rounded at the base, which is above, and truncated at its apex, which is beneath. It is of small size; its length being only about two and a half inches; breadth one and a half inch at the base, and ten lines at the neck; thickness about an inch. It is divided into the *fundus*, *body*, and *cervix* or *neck*. The fundus is the upper part of the organ above the insertion of the Fallopian tubes. The body is the part between the insertion of the tubes and the neck; and the neck is the lowest and narrowest portion, which projects and opens into the vagina. At each of the two superior angles are—the opening of the Fallopian tube, the attachment of the ligament of the ovary, and that

[1] **Medical Examiner, for December, 1846, p. 703.**

of the round ligament. The inferior angle is formed by the neck, which projects into the vagina to the distance of four or five lines, and terminates by a cleft, situate crosswise, called *os tincæ*, *os uteri* or *vaginal orifice of the uterus.* The aperture is bounded by two lips, which are smooth and rounded in those that have not had children; jagged and rugous in those who are mothers,—the anterior lip being somewhat thicker than the posterior. It is from three to five lines long, and is generally more or less open, especially in those who have had children. The internal cavity of the uterus is very small in proportion to the bulk of the organ, owing to the thickness of the parietes, which almost touch internally. It is divided into the cavity of the body, and that of the neck. (Fig. 418.) The former is triangular. The tubes open at its upper angles. The second cavity is more long than broad; is broader at the middle than at either end; and at the upper part where it communicates with the cavity of the body of the uterus an opening exists, called *internal orifice* of the uterus; the *external orifice* being the os uteri. The inner surface has several transverse rugæ, which are not very prominent. It is covered by fine villi, and the orifices of several mucous follicles are visible.

Fig. 418.



Section of Uterus.

The precise organization of the uterus has been a topic of interesting inquiry amongst anatomists. It is usually considered to be formed of two parts, a mucous membrane internally, and the proper tissue of the uterus, which constitutes the principal part of the substance. The mucous membrane has been esteemed a prolongation of that which lines the vagina. It is very thin; of a red hue in the cavity of the body of the organ; white in that of the neck. Chaussier, Ribes, and Madame Boivin, however, deny its existence. Chaussier asserts, that having macerated the uterus, and a part of the vagina, in water, vinegar, and alkaline solutions; and having subjected them to continued ebullition, he always observed the mucous membrane of the vagina stop at the edge of the os uteri; and Madame Boivin,—a well-known French authoress on obstetrics, who has attended carefully to the anatomy of those organs during pregnancy,—says, that the mucous membrane of the vagina terminates by small expansible folds, and by a kind of prepuce, under the anterior lip of the os uteri. In their view, the inner surface of the uterus is formed of the same tissue as the rest of it. The epithelium of the vagina differs, however, from that of the uterus. It is columnar and ciliated as far down as the middle of the cervix uteri, below which it becomes tesselated or squamous, like that of the vagina.

When examined with a lens, the mucous membrane is found to be marked over with minute dots, which are the orifices of numerous simple tubular glands; some of these are branched and others slightly twisted into a coil. They can be seen in the virgin uterus; but become enlarged on impregnation. The proper tissue of the organ is dense, compact, not easily cut, and somewhat resembles cartilage in colour, resistance, and elasticity. It is a whitish, homogeneous substance, penetrated by numerous minute vessels. In the unimpregnated state, the fibres, which enter into the composition of the tissue, appear ligamentous, and pass in every direction, but so as to permit the uterus to be more readily lacerated from the circumference to the centre than in any other direction. The precise character of the tissue has been a matter of contention amongst anatomists. The microscope shows it to be composed of muscular fibres of the unstriped variety, interlacing with each other, but disposed in bands and layers, intermixed with much fibro-areolar tissue, a large number of bloodvessels and lymphatics, and a few nerves. The arrangement of the muscular fibres is best studied at an advanced period of utero-gestation. Besides the usual organic constituents, the uterus has arteries, veins, lymphatics, and nerves. The arteries proceed from two sources;—the spermatic, which are chiefly distributed to the fundus of the organ, and towards the part where the Fallopian tubes terminate; and the hypogastric, which are sent especially to the body and neck. Their principal branches are readily seen under the peritoneum, which covers the organ; they are very tortuous; frequently anastomose, and their ramifications are lost in the tissue of the viscus, and on its inner surface. The veins empty themselves partly into the spermatic, and partly into the hypogastric. They are even more tortuous than the arteries; and, during pregnancy, dilate and form what have been termed *uterine sinuses*. The nerves are derived partly from the great sympathetic, and partly from the sacral pairs. The arrangement of the uterine nerves has given rise to much difference of sentiment. Whilst Dr. Lee[1] considers that the uterus is

Fig. 419.

Section of the Paries of the Uterus magnified three diameters.

The right hand portion is the fibrous structure of the uterus; the left hand the lining membrane and tubular glands. The arrangement of the vessels accompanying these is shown.

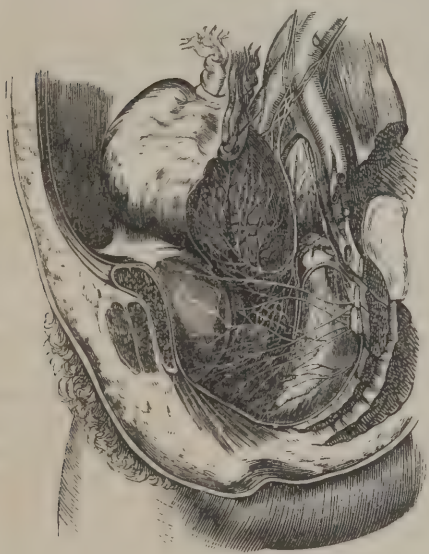
[1] The Anatomy of the Nerves of the Uterus, Lond., 1841; Philosophical Transactions for 1842; and Lectures on the Theory and Practice of Midwifery, Amer. edit., p. 108, Philad., 1844; see, also, W. Tyler Smith, Parturition, and the Principles and Practice of Obstetrics, p. 79, Philad., 1849.

most copiously supplied with them; others—as Mr. Beck,[1] Dr. Sharpey[2] and M. Boulard[3]—have supposed, that he mistook for nerves other structures; and that the number of uterine nerves is by no means great.

The uterus is sometimes absent.[4]

The appendages of the uterus are:—1. The *ligamenta lata* or *broad ligaments*, which are formed by the peritoneum. This membrane is reflected over the anterior and posterior surfaces and over the fundus of the uterus; and the lateral duplicatures of it form a broad expansion, and envelope the Fallopian tubes and ovaria. These expansions are the broad ligaments. (See Figs. 415 and 416.) 2. The *anterior* and *posterior ligaments*, which are four in number and are formed by the peritoneum. Two of these pass from the uterus to the bladder,—the *anterior;* and two between the rectum and uterus—the *posterior*. 3. The *ligamenta rotunda* or *round ligaments*, (Fig. 415,) which are about the size of a goose-quill, arise from the superior angles of the fundus uteri, and, proceeding obliquely downwards and outwards, pass out through the abdominal rings to be lost in the areolar tissue of the groins. They are whitish, somewhat dense cords, formed by a collection of tortuous veins and lymphatics, nerves, and longitudinal fibres, which were, at one time, believed to be muscular, but are now generally considered to consist of condensed areolar tissue. 4. The *Fallopian* or *uterine tubes;* two conical, tortuous canals, four or five inches in length; situate in the same broad ligaments that contain the ovaries, and extending from the superior angles of the uterus as far as the lateral parts of the brim of the pelvis. (Figs. 415, 416, and 421.) The uterine extremity of the tube (Figs. 416 and 421) is extremely small, and opens into the uterus by an aperture so minute as scarcely

Fig. 420.



Nerves of the Uterus.

[1] Philosophical Transactions, part 2, for 1846.

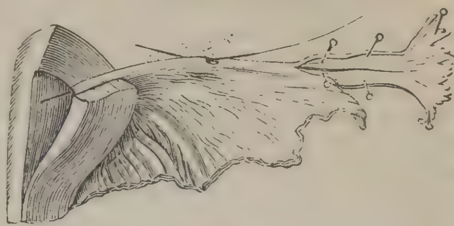
[2] Quain's Human Anatomy, by Quain and Sharpey, Amer. edit., by Dr. Leidy, ii. 356, Philad., 1849.

[3] Comptes Rendus des Séances et Mémoires de la Société de Biologie, Tom. 3, p. 86, Année, 1851.

[4] For such cases, see Dr. Chew, Amer. Journ. Med. Sciences, May, 1840, p. 39; also, Dr. Meigs, translation of Colombat de l'Isère on Diseases of Females, p. 119, Philad., 1845.

to admit a hog's bristle. The other extremity is called *pavilion.* It is trumpet-shaped, fringed, and commonly inclined towards the ovary, to which it is attached by one of its longest fimbriæ. This fringed portion is called *corpus fimbriatum* or *morsus diaboli.* The Fallopian tubes, consequently, open at one end into the cavity of the uterus, and at the other, through the peritoneum into the cavity of the abdomen. They are covered externally by the broad ligament or peritoneum; are lined internally by a mucous membrane, which is soft, villous, and has many longitudinal folds; and between these coats is a thick, dense, whitish membrane, which is possessed of contractility; although muscular fibres cannot be detected in it. Santorini asserts that in robust females the middle membrane of the tubes has two muscular layers; an external, the fibres of which are longitudinal; and an internal, whose fibres are circular.

Fig. 421.

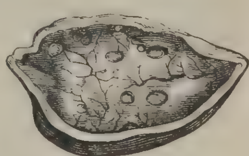


Fallopian Tube.

M. Raciborski,[1] in a memoir read to the *Académie Royale des Sciences* of Paris, states it to be a general rule, that the extremities of the Fallopian tube in domestic animals are so placed during the act of fecundation as to envelope the entire ovary, either directly by means of the open trumpet-shaped extremity, or indirectly by the aid of the fimbriated extremity. In women, however, the fimbriated extremity embraces but a small portion of the ovary; and he thinks, that this anatomical peculiarity is the cause of extra uterine conception being so much more common in them than in domestic animals. In the latter, indeed, it is very rare.

The *ovaries* (Figs. 416 and 422) are two ovoid bodies, of a pale red colour; rugous, and nearly of the size of the testes of the male. They are situate in the cavity of the pelvis, and are contained in the posterior fold of the broad ligaments of the uterus. At one time they were conceived to be glandular, and were called the female testes; but as soon as the notion prevailed that they contained ova, the term *ovary* or *egg vessel* was given to them. The external extremity of the ovary has attached to it one of the principal fimbriæ of the Fallopian tube. The inner extremity has a small fibro-vascular cord inserted into it; this passes to the uterus, to which it is attached behind the insertion of the Fallopian tube; and a little lower. It is called *ligament of the ovary,* and is in the posterior ala of the broad ligament. It is solid, and has no canal. The surface of the ovary has many round prominences, and the peritoneum—forming the *indusium*—envelopes the whole of it,

Fig. 422.



Section of Ovary.

[1] Gazette Médicale de Paris, 25 Juin, 1842.

except at the part where the ovary adheres to the broad ligament. The precise nature of its parenchyma or *stroma* is not determined. When torn or divided longitudinally, as in Fig. 422, it appears to be constituted of a cellulo-vascular tissue. In this, there are spherical vesicle—*ovula Graafiana*, *folliculi Graafiani*, *follicles of De Graaf*, *Graafian follicles*, *ovi-capsules* or *ovisacs*. Roederer[1] asserts, that he found in the ovary of one woman thirty, in that of another about fifty. These are filled with an albuminous fluid, which is colourless or yellowish, and may be readily seen by dividing the vesicles carefully with the point of a fine scissors. The examinations of recent histologists, however, show, that the number is far beyond that mentioned by Roederer and others. At the period of puberty, the stroma of the ovary is crowded with ovisacs, which are still so minute, that in the cow, according to the computation of Dr. Barry, a cubic inch would contain 200 millions of them. Fluid from the ovary of a mare was examined by M. Lassaigne, and found to contain albumen, with chlorides of sodium and potassium.

In the lower animals, the ovary consists of a loose tissue, containing many cells, in which the ova are formed, and from which they escape by the rupture of the cell-walls: in the higher animals, as in the human female, the tissue is more compact, and the ova, except when they are approaching maturity, can only be distinguished by the aid of a high magnifying power.

The microscopic analysis of the ovum has greatly engaged the attention of modern histologists, who have materially extended our knowledge in regard to it; although we have still much to learn. In the egg of the fowl, the parts more interesting in the present relation are the yolk membrane and its contents; for neither the albumen which forms the white, nor the shell membrane with its calcareous covering, exists in the ovum whilst in the ovary. They are added during its passage through the oviduct. Within the yolk, or vitellary membrane—*cuticula vitelli*—is the yolk—*vitellus*—consisting partly of albuminous granules, and partly of oil globules. Towards the centre, the yolk changes in some degree, being of a lighter colour, and the granules having more the appearance of cells, with minuter globules in their interior. The central portion is termed *discus vitellinus*. In the centre of the yolk of the unripe ovule is a larger cell, distinct in appearance from the rest, and having a nucleus in its walls. This is the *germinal vesicle*, or vesicle of Purkinje, so called from its first describer, and the nucleus is the *germinal spot*. In man and the mammalia, the ova contain the same

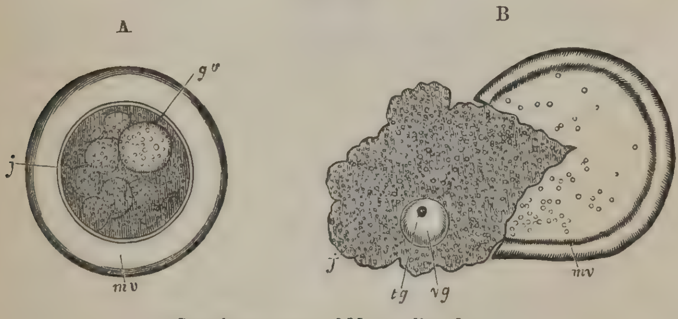
Fig. 423.

New-laid Egg with its Molecule, &c.

[1] Stannius, art. Eierstock, in Encyclop. Wörterb., u. s. w., x. 188, Berlin, 1836.

parts; but, even when advanced, they are exceedingly minute, owing to the small quantity of vitellus that enters into their composition. The ripest ovum in the ovary of the human subject, and of the mammalia, does not generally measure more than from the fifteenth to the twentieth part of a line in diameter: it rarely happens, that they are as much as $\frac{1}{10}$th of a line. They vary, according to Bischoff, from $\frac{1}{240}$th to $\frac{1}{120}$th of an inch. Under the microscope, the Graafian vesicle is found to consist of an external and an internal membrane. The former—*tunic of the ovisac*, of Dr. Barry,[1] is extremely vascular; the latter, *ovisac* of the same observer—*membrana propria* of some—*vésicule ovulifère* of M. Pouchet[2]—is smooth and velvety, and derives its vessels from the former. The cavity, enclosed by these membranes, is far from being filled by the ovum; it contains, besides, a whitish or yellowish albuminous mass, which consists chiefly of granules, from the three hundredth to the two hundredth part of a line in diameter, connected together by a tenacious fluid, forming the *membrana granulosa*,—*couche celluleuse* of M. Coste.[3] Its density is unequal, and, towards some part of the periphery of the vesicle, these granules are accumulated in a disk-like form, making a slight prominence, in which there is a depression. The disk is termed by Von Baer *discus proligerus;* and it has been called *discus vitellinus.* The prominence has been

Fig. 424.



Constituent parts of Mammalian Ovum.

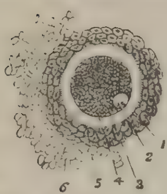
A. Entire. B. Ruptured, with the contents escaping. *m v.* Vitelline membrane. *j.* Yolk. *v g.* Germinal vesicle. *t g.* Germinal spot.

named *cumulus*, *germinal cumulus*, *cumulus proligerus*, *nucleus cicatriculæ* and *nucleus blastodermatis.* Dr. Barry likewise observed certain granular cords, resembling both in appearance and function the chalazæ of the egg, which he has called *retinacula*, but which Bischoff does not admit. A small cup-like cavity in the cumulus receives the ovum. The ovum is surrounded by a thick white ring, which has been called *zona pellucida*, and has been considered to be a membrane; but, according to Mr. T. W. Jones, is now pretty generally acknowledged to be "the optical expression of the circumferential doubling of a thick transparent membrane, which encloses the yolk." Within this, is a granular

[1] Philos. Transact. for 1838.
[2] Théorie positive de l'Ovulation spontanée, p. 44, Paris, 1847.
[3] Histoire générale et particulière du Développement des Corps Organisés, i. 163, Paris, 1847.

layer—the *vitellus* or *yolk*—the larger granules of which are superficial and compact; whilst, internally, it is a clear albuminous fluid almost

Fig. 425.



Ovum of the Sow.

1. Germinal spot. 2. Germinal vesicle. 3. Yolk. 4. Zona pellucida. 5. Discus proligerus. 6. Adherent granules or cells.

Fig. 426.

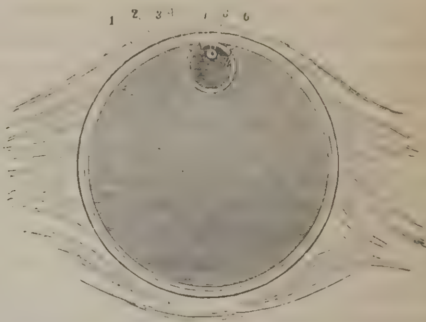
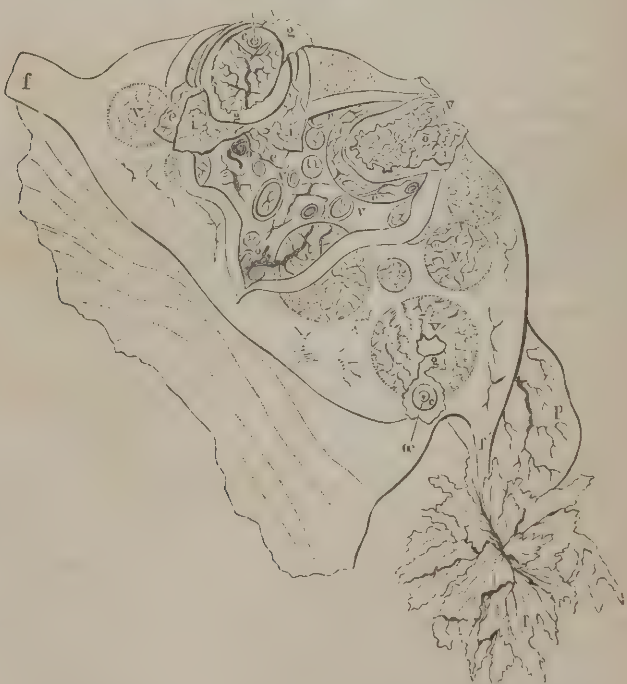


Diagram of a Graafian Vesicle, containing an Ovum.

1. Stroma or tissue of the ovary. 2 and 3. External and internal tunics of the Graafian vesicle. 4. Cavity of the vesicle. 5. Thick tunic of the ovum or yolk-sac. 6. The yolk. 7. The germinal vesicle. 8. The germinal spot.

Fig. 427.



Ovarium laid open, with Graafian vesicles in various stages of evolution.

At *p*, is shown the expanded fimbria of the Fallopian tube, near which is seen to project from the surface of the ovary a Graafian vesicle, *v*, the rupture of which has allowed an ovule, œ, surrounded by its discus proligerus, *c*, to escape:—in the centre of the upper part of the figure is shown an emptied Graafian vesicle, *v*, laid open by the incision, and showing the irregular cavity, *g*;—further up, towards the left, is seen another Graafian vesicle, with the ovum *c*, not yet discharged. Other Graafian vesicles, *c*, *v*, *v*, in earlier stages of developement, are seen in different parts of the figure.

devoid of granules. Imbedded in the vitellus, but nearer its circumference than its centre, is the *germinal vesicle* or *vesicle of Purkinje*, first seen in the mammalia by M. Coste,[1] which appears like a clear ring of very small size, and measures in man and the mammalia not more than $\frac{1}{60}$th part of a line in diameter. Upon a particular part of the germinal vesicle is observed the *macula germinativa* or *germinal spot*, which presents itself as a rounded granular formation attached to the inner wall of the germinal vesicle. All these parts are represented in Fig. 426. Wagner[2] thinks the germinal vesicle may be viewed as a cell—a primary cell—of which the germinal spot forms the nucleus, and that it would perhaps be well to style the germinal spot *germinal nucleus.*

It was elsewhere remarked,[3] that the formation of the ovule by the Graafian follicle must be regarded as a true secretion,—the yolk of which it is mainly composed as well as the membrana granulosa essentially resembling each other in histological and chemical character. When maturated, the ovum, pressed forward probably by fresh depositions of the yellow matter which goes to the formation of the granular membrane and the yolk, is discharged from the ovary, and laid hold of by the Fallopian tube, which acts as an excretory duct, and conveys it into the interior of the uterus.

Fig. 428.

Ovarium of the living Hen, natural size. The Ova at different stages of evolution.

The observations of Carus[4] have shown, that the vesicles of De Graaf exist even in the fœtus; and according to Dr. Ritchie,[5] it would seem that during the period of childhood, there is a continual rupture of ovisacs, and discharge of ova at the surface of the ovarium.[6] The ovaria are studded with numerous minute copper-coloured spots; and their surface presents delicate vesicular elevations, occasioned by the most

[1] Bischoff, Traité du Développement de l'Homme et des Mammifères, traduit par Jourdan, p. 6, Paris, 1843.

[2] Human Physiology, translated by R. Willis, p. 43, Lond., 1841.

[3] Vol. i. p. 507.

[4] Gazette Médicale de Paris, Aug. 12, 1837.

[5] Lond. Med. Gazette, 1844.

[6] Kirkes and Paget, Handbook of Physiology, Amer. edit., p. 461, Philad., 1849.

matured ovisacs: the escape of these takes place by minute punctiform openings in the peritoneal coat, and no cicatrix is left. The different conditions of progress towards maturation are well seen in the ovary or yolk bag of the common fowl.

The arteries and veins of the ovaries belong to the spermatic. The arteries pass between the two layers of the broad ligament to the ovary, assuming there a beautiful convoluted arrangement, very similar to the convoluted arteries of the testis. These vessels traverse the ovary nearly in parallel lines, as in the marginal figure, forming numerous minute twigs, which have an irregular knotty appearance, from their tortuous condition; and appear to be chiefly distributed to the Graafian vesicles. The nerves of the ovaries, which are extremely delicate, are from the renal plexuses; and their lymphatics communicate with those of the kidneys.[1]

Such is the anatomy of the chief organs concerned in the function of generation. Those of lactation will be described hereafter.

1. MENSTRUATION.

Before proceeding to the physiology of generation, there is a function, peculiar to the female, which requires consideration. This consists in a periodical discharge of blood from the vulva, occurring from three to six days in every month, during the whole time that the female is capable of conceiving,—or from the period of puberty to what has been termed the *critical age*. This discharge is called *catamenia*, *menses*, *flowers*, &c., and the process *menstruation*. It has been considered peculiar to the human species; but MM. Geoffroy St. Hilaire, and F. Cuvier, assert, that they have discovered indications of it in the females of certain animals. It has been denied, however, that this is anything more than the exudation of a bloody mucus. At the present day, however, menstruation is maintained by many to be identical with the *rut* of animals.

In some females, it is established suddenly, and without any premonitory phenomena; but in the greater number it is preceded and accompanied by some inconvenience. The female complains of signs of plethora or general excitement,—indicated by redness and heat of skin, heaviness in the head, oppression, quick pulse, and pains in the back or abdomen. The discharge commences drop by drop, but continuously; during the first twenty-four hours, the flow is not as great as afterwards, and is more of a serous character; but, on the following day, it becomes more abundant and sanguineous, and gradually subsides, leaving, in many females, a whitish, mucous discharge, technically termed *leucorrhœa*, and, in popular language, the *whites*.

The quantity of fluid lost, during each menstruation, varies greatly according to the individual and the climate. Its average is supposed to be from six to eight ounces in temperate regions. By some, it has been estimated as high as twenty. Dr. Meigs[2] states, that he has met with many healthy women, who informed him, that they never used a napkin; so that, he observes, it is not possible to conceive, that in such

[1] See Kobelt De l'Appareil du Sens Génital des deux Sexes, traduit de l'Allemand, par H. Kaula, D. M., Strasbourg & Paris, 1851.

[2] Edit. of Colombat de l'Isère on the Diseases, &c., of Females, p. 33, Philad., 1845.

persons the loss amounts to more than three or four ounces. It is difficult, indeed, to imagine that it can amount to so much. On the other hand, he is confident, that many healthy females lose at least 20 ounces at each period.

The fluid proceeds from the interior of the uterus, and not from the vagina. At one time, it was believed, that in the intervals between the flow of the menses, the blood gradually accumulates in some parts of the uterus, and when these parts attain a certain degree of fulness, they give way, and it flows. This office was ascribed to the cells, which were conceived to exist in the substance of the uterus between the uterine arteries and veins,—and, by some, to the veins themselves, which, owing to their great size, were presumed to be reservoirs, and hence called *uterine sinuses*. The objection to these views is,—that we have no evidence of the existence of any such accumulation; and that when the interior of the uterus of one who has died during menstruation is examined, there are no signs of any such rupture as that described; the enlarged vessels exist only during pregnancy or during the expanded state of the uterus; the veins in the unimpregnated organ are small, and totally inadequate for such a purpose.

The menstrual fluid is a true exhalation, effected from the inner surface of the uterus. This is evident from the change in the lining membrane of the organ during the period of its flow, which is rendered softer and more villous, and exhibits bloody spots, with numerous pores from which the fluid may be expressed. An injection, sent into the arteries of the uterus, also readily transudes through the lining membrane. The appearance of the menstrual fluid in the cavity of the uterus, during the period of its flow; its suppression in various morbid conditions of the organ; and the direct evidence, furnished to Ruysch, Blundell,[1] Sir C. Clarke,[2] and others, in cases of prolapsus or inversio uteri, where the fluid has been seen distilling from the uterus, likewise show that it is a uterine exhalation.

Much discussion has occurred as to whether the catamenia are the result of simple hemorrhage; or are a true secretion from the uterine blood. From ordinary blood they may be distinguished by the smell, which is *sui generis*, and also by not being coagulable. "It [the menstrual fluid] is," says Mr. Hunter, "neither similar to blood taken from a vein of the same person, nor to that which is extravasated by accident in any other part of the body, but is a species of blood, changed, separated, or thrown off from the common mass by an action of the vessels of the uterus, similar to that of secretion, by which action the blood loses the principle of coagulation, and, I suppose, life." The principle of coagulation does not exist,—according to Lavagna, Toulmouche, J. Müller and others,[3] owing to the absence of fibrin. Retzius[4] asserts, that he has detected it in free phosphoric and lactic acids, by the presence of which, he conceives, the fibrin is kept in a state of

[1] Principles and Practice of Obstetricy, Amer. edit., p. 49, Washington, 1834.
[2] On Diseases of Females attended with Discharges, Amer. edit., Philad., 1824.
[3] Handbuch der Physiologie, Baly's translation, p. 256, Lond., 1837, and p. 1481, Lond., 1842.
[4] Ars. Berättelse af Setterblad, 1835, Seite 19—cited in Zeitschrift für die Gesammte Medicin, Marz, 1837, S. 390.

solution, and prevented from coagulating. The fluid has the properties, according to Mr. Brande, of a very concentrated solution of the colouring matter of the blood in a dilute serum.[1] Dr. Burow[2] examined twelve ounces of menstrual blood, which had been retained in the uterus by an imperforate hymen. It was of a dirty reddish-brown colour, of the consistence of syrup, very adhesive, and entirely devoid of odour; abounded in albumen, and was very little susceptible of putrefaction. When examined with the microscope, almost all the blood-corpuscles were found to have lost their regular form, and to resemble the granules observed in pus which has been for a long time exposed to the air, or retained within the cavity of an abscess. These blood-corpuscles were suspended in a transparent fluid. On stirring the blood for a considerable time, no perceptible change was produced to the eye; but under the microscope numerous delicate, transparent lamellæ were seen floating in the serum, which Dr. Burow regarded as portions of fibrin, a substance sparingly present—as has been remarked—in menstrual blood. The red colour of the menstrual fluid was found by Remak[3] to be owing to the presence of blood-corpuscles, and the intensity of the colour to their number. M. Bouchardat[4] analyzed the menstrual fluid, obtained from a female who permitted a speculum to remain in the vagina for ten hours in order that an ounce might be procured. Without this precaution, the fluid becomes mixed with vaginal mucus and urine, as the presence of ammoniaco-magnesian phosphate demonstrates. The following were the results of the analysis:—Water, 90·8; fixed matters, 6·92. The fixed matters were composed of—fibrin, albumen, and colouring matter, 75·27; extractive matter, 0·42; fatty matter, 2·21; salts, 5·31; mucus, 16·79. The female was a patient of M. Brière de Boismont, who considers, that the large proportion of water was due to the delicacy of her frame, and to her subsisting on vegetable diet (?).

A specimen of menstrual blood was examined by M. Simon,[5] and found to be composed of water, 785·000; solid constituents, 215·000; fat, 2·580; albumen, 76·540; hemato-globulin, 120·400; extractive matters and salts, 8·600. It contained no fibrin. Its most striking peculiarities were;—the total absence of fibrin, and the increase of solid constituents caused by the excess of blood-corpuscles. The hemato-globulin was found to be very rich in hematin, combined, undoubtedly, with a considerable amount of hemaphæin. The colouring matter amounted to 8·3% of the hemato-globulin. Dr. Day[6] has, however, little doubt that fibrin exists in the menstrual secretion; but its detection is usually rendered impracticable, owing to the presence of a large amount of mucus, which seems to deprive the blood of its power of coagulating.

In an analysis made by M. Denis, and cited by M. Coste,[7] the men-

[1] Philos. Transact., ciii. 113; and Blundell, op. cit., p. 46.
[2] Müller's Archiv., No. vii. 1840; and Brit. and For. Med. Rev., July, 1840, p. 287.
[3] Medicinische Zeitung, 25 Déc., 1839.
[4] Brière de Boismont, De la Menstruation, &c., Paris, 1842.
[5] Animal Chemistry, by Day, Sydenham edit., p. 337, Lond., 1845. [6] Ibid.
[7] Histoire Générale et Particulière du Développement des Corps Organisés, p. 224, Paris, 1847.

strual fluid was found to consist of water, 82·50; fibrin, 0·05; hematosin, 6·34; mucus, 4·53; albumen, 4·83; oxide of iron, 0·05; red phosphuretted fat and traces of white phosphuretted fat, 0·39; osmazome and cruorin, of each, 0·11; subcarbonate, chlorohydrate of soda, and chlorohydrate of potassa, of each, 0·95; carbonate of lime and sulphate of lime, 0·25; traces of phosphate of magnesia:—the whole consisting of 82·50 watery parts; 10·70 parts in suspension and in globules; and 6·58 parts in solution.

Rindskopf analyzed the menstrual discharge of a healthy vigorous girl. It was extremely acid, and contained, on the first analysis, water, 820·830; solid residue, 179·170; salts, 10·150;—in the second, water, 822·892; albumen and hemato-globulin, 156·457; extractive matter and salts, 20·651. Another specimen of menstrual fluid, examined by M. Donné, presented the following appearances under the microscope. 1. Abundance of ordinary corpuscles of the blood. 2. Vaginal mucus, formed of epidermic scales from the mucous membrane. 3. Mucous globules, furnished by the neck of the uterus (?). In more than fifty specimens of the ordinary menstrual fluid, examined by Mr. Whitehead,[1] the following were the results:—its acid nature was in every instance unequivocal; its colour was similar to that of healthy venous blood, never so florid as that from the arteries; and it was less viscid than either; it did not coagulate, but occasionally—when very profuse owing to over-exertion, mental anxiety, or confinement to a heated atmosphere—clots were observed, which always had an alkaline reaction: under the microscope blood-corpuscles in linear or irregular groups were always observable, floating in a pale, pinkish serum; and occasionally a few lymph globules were perceptible, with a number of small granular bodies like oil globules: there was always, also, in it a great quantity of epithelial scales of different shapes and sizes.

So far, therefore, as examinations go, they show, that there is much resemblance between the catamenial discharge and blood. M. Donné,[2] indeed, affirms, that they appear to him to differ in no respect; and, that if the former has occasionally an acid reaction, in place of being alkaline like ordinary blood, this is simply owing to its being mixed with a considerable quantity of vaginal mucus, which is always extremely acid; whilst uterine mucus, he affirms, is always alkaline.[3] In an analysis, however, by Dr. Letheby,[4] of menstrual fluid retained by an imperforate hymen, no fibrin was detected, and it had an alkaline reaction.

The question, whether it be a secretion or a periodical hemorrhage is one of slight moment. They, who are of the former opinion, believe, that the fluid differs somewhat from blood as contained in the vessels; and if such difference really exists, they must regard it as a secretion. Moreover, at the commencement and termination of the sanguineous flow, the discharged fluid is certainly a secretion; and prior to, and during the whole of the menstrual period the lining

[1] On the Causes and Treatment of Abortion and Sterility, Amer. edit., p. 40, Philad., 1848.

[2] Cours de Microscopie, p. 139, Paris, 1844.

[3] Ibid., p. 155.

[4] Lancet, Aug. 2, 1845.

membrane is in a state of erethism, and, doubtless, the seat of increased and modified secretion. The occurrence of menstruation is commonly indicated by a peculiar odour in the secretions from the vulva, so characteristic of the act which it announces, that, according to Pouchet, from it alone the approach of the catamenia may be predicted.[1] They, on the other hand, who maintain the latter opinion, believe the fluid to be pure blood, which subsequently becomes mixed with the utero-vaginal secretions; and that the peculiar odour is occasioned by such admixture. The author has been assured, however, by one observer, that in a case of vicarious catamenial discharge, which took place from the hairy scalp, the peculiar odour was distinctly evinced. This is a point which merits farther observation. That the flow takes place from the arteries and not from the veins, is favoured by the fact, that when injections are sent into the uterine arteries they transude through the lining membrane of the uterus; and the analogy of all the other exhalations is confirmatory of the position.

The efficient cause of menstruation has afforded ample scope for speculation and hypothesis. As its recurrence corresponds to a revolution of the moon around the earth, lunar influence has been invoked; but, before this solution can be admitted, it must be shown, that the effect of lunar attraction is different in the various relative positions of the moon and earth. There is no day in the month, in which numerous females do not commence their menstrual flux; and, whilst the discharge is beginning with some, it is at its acme or decline with others. The hypothesis of lunar influence must therefore be rejected. In the time of Van Helmont,[2] it was believed, that a ferment exists in the uterus, which gives occasion to a periodical intestine motion in the vessels, and a recurrence of the discharge; but independently of the want of evidence of the existence of such a ferment, the difficulty remains of accounting for its regular renovation every month. Local and general plethora have been assigned as causes; and many of the circumstances, that modify the flow, favour the opinion. The fact of what has been called *vicarious menstruation*, has been urged in support of this view. In these cases, instead of the menstrual flux taking place from the uterus, hemorrhage occurs from various other parts of the body, as the breast, lungs, ears, eyes, nose, &c., which would appear to indicate, that there is a necessity for the monthly evacuation or *purgation*, Reinigung, as the French and Germans term it; and that if this be obstructed, a vicarious hemorrhage may be established; yet the loss of several times the quantity of blood from the arm, previous to, or in the very act of, menstruation does not always prevent, or interrupt the flow of the catamenia; and in those maladies, which are caused by their obstruction, greater relief is afforded by the flow of a few drops from the uterus itself, than of ten times the quantity from any other part.

Some of the believers in local plethora of the uterus have maintained, that the arteries of the pelvis are more relaxed in the female than in the male, and the veins more unyielding; and hence, that the

[1] Coste, Histoire Générale et Particulière du Développement des Corps Organisés, i. 203, Paris, 1847.

[2] Opera, edit. 4, p. 440, Lugd. Bat., 1667.

first of these vessels convey more blood than the second return. It has been, also, affirmed, that whilst the arteries of the head predominate in man by reason of his being more disposed for intellectual meditation, the pelvic and uterine arteries predominate in the female, owing to her destination being more especially for reproduction. Setting aside all these gratuitous assumptions, it is obvious that a state, if not of plethora, at least of irritation, must occur in the uterus every month, which gives occasion to the menstrual secretion; but as M. Adelon[1] has properly remarked, it is not possible to say why this irritation is renewed monthly, any more than to explain, why the predominance of one organ succeeds that of another in the progress of age. The function is as natural, as instinctive to the female, as the developement of the whole sexual system at the period of puberty. That it is connected most materially with the capability of reproduction is shown by the fact, that it does not make its appearance until puberty, —the period at which the young female is capable of conceiving,— and disappears at the critical time of life, when conception is impracticable. It is arrested, too, as a general rule, during pregnancy and lactation; and in amenorrhœa or obstruction of the menses, fecundation is not readily effected. In that variety, indeed, of menstruation, which is accomplished with much pain at every period, and is accompanied by the secretion of a membranous substance having the shape of the uterine cavity, conception may be esteemed impracticable. Professor Hamilton, of the University of Edinburgh, was in the habit of adducing this in his lectures, as one of two circumstances—the other being the want of a uterus—that are invincible obstacles to fecundation. Yet, in the case of dysmenorrhœa of the kind mentioned, if the female can be made to pass one monthly period without suffering, or without the morbid secretion from the uterine cavity, she may become pregnant, and the whole of the evil be removed: for, the effect of pregnancy being to arrest the catamenia, the morbid habit is usually got rid of during gestation and lactation; and may not subsequently recur.

Gall[2] strangely supposed, that some general but extraneous cause of menstruation exists, other than the influence of the moon; and affirms, that in all countries females generally menstruate about the same time;—that there are, consequently, periods of the month in which none are in that condition; and he affirms, that all females may, in this respect, be divided into two classes;—the one comprising those who menstruate in the first eight days of the month, and the other, those who are "unwell"—as it is termed by them in some countries— in the last fortnight. He does not, however, attempt to divine what this cause is. We are satisfied, that his positions are erroneous. Observation has led to the knowledge, already stated, that there is no period of the moon at which the catamenial discharge is not taking place in some; and we have not the slightest reason for supposing, that, on the average, more females are menstruating at one part of the month than at another. It would seem, however, that there are cir-

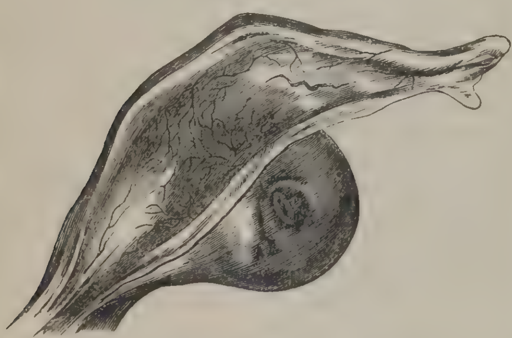
[1] Physiologie de l'Homme, 2de édit., iv. 48, Paris, 1829.
[2] Sur les Fonctions du Cerveau, iv. 355.

cumstances in the economy, which, as in the case of fevers, give occasion to something like periodicity at intervals of seven days;—for example, Mr. Roberton,[1] of Manchester, England, asserts, that of 100 women, the catamenia returned every fourth week in 68; every third week in 28; every second week in 1; and at irregular intervals in 10; these varieties usually existing as family and constitutional peculiarities.

It is scarcely necessary to notice the visionary speculations of those who have regarded menstruation as a mechanical consequence of the erect attitude; or the opinion of Roussel,[2] that it originally did not exist, but was produced artificially by too succulent and nutritious a regimen, and afterwards propagated from generation to generation; or, finally, that of Aubert, who maintained, that if the first amorous inclinations were satisfied, the resulting pregnancy would totally prevent the establishment of menstruation. The function, it need scarcely be repeated, is instinctive; and forms an essential part of the female constitution.

MM. Négrier, Gendrin,[3] and others, have revived a view entertained by Mr. Cruikshank, Dr. Power,[4] and others, that menstruation is dependent upon changes occurring periodically in the ovary. Many cases have been related by Cruikshank, Robert Lee, Gendrin, Négrier, Bischoff, Pouchet, and others,[5] in which, on the dissection of females, who had died during menstruation, evidences have been afforded of the rupture of an ovarian vesicle, and of a small, irregular rupture or cicatrix in the coats of the ovarium, as represented in the marginal figure, which communicated with the remains of a Graafian vesicle; whence it has been inferred, that during the whole of that period of life when the capability for conception continues, there is a constantly successive developement of vesicles and their contained ovules in the ovary, and that, at each epoch of menstruation, a vesicle having reached the surface of the ovary becomes the seat of a peculiar organic action, in which all the organs of generation participate; and that the result of this action is the rupture of the vesicle, and the loss of the infecund ovum, either by expulsion from the uterus or by destruction

Fig. 429.



Ovary of a Female dying during Menstruation.

[1] Edinb. Med. and Surg. Journal, xxxviii. 237.
[2] Système Physique, &c., de la Femme, p. 13, Paris, 1809.
[3] Traité Philosophique de M decine Pratique, Paris, 1838–9.
[4] An Essay on the Periodical Discharge, &c., London, 1832.
[5] See, on this subject, Coste, Histoire Générale et Particulière du Développement des Corps Organisés, p. 195, Paris, 1847.

in the ovary. Subsequently, M. Raciborski[1] maintained as the result of his researches,—*First.* That there exists the most intimate connexion between the Graafian vesicles and menstruation. When the vesicles arrive at their full developement, menstruation commences, and when they are destroyed it ceases. *Secondly.* At each menstrual period, a follicle projects like a nipple on the surface of the ovary, where it afterwards bursts, without requiring for that purpose any venereal excitement. *Thirdly.* The rupture of the follicles generally appears to take place at the period when the menstrual discharge is stopping; and *Fourthly.* The ovaries do not act alternately, as has been affirmed;—in this respect not seeming to be under any fixed law. In a more recent work,[2] he asserts the doctrine, that the catamenia are but a secondary phenomenon in menstruation properly so called; that the capital phenomenon is the maturation and periodical discharge (*ponte*) of ova; and hence a woman may give birth to several children without ever having seen the catamenia.[3]

Of late years, much attention has been given to this subject, and by none more than by Dr. Ritchie,[4] of Glasgow. As before remarked, this gentleman affirms, that even during the period of childhood, there is a continual rupture of ovisacs, and discharge of ova at the surface of the ovary. About the period of puberty—he states—a marked change usually takes place in the mode in which the ovisacs discharge their contents; but this change does not necessarily occur simultaneously with the first appearance of the catamenia. The ovaries now receive a much larger supply of blood, and the ovisacs exhibit a great increase of bulk and vascularity, so that when they appear at the surface of the ovary, they resemble pisiform turgid elevations; and the discharge of their contents leaves a much larger cicatrix, and is accompanied by an effusion of blood into their cavities. It would appear, however, from Dr. Ritchie's observations, that although this discharge takes place most frequently at the menstrual period, the two occurrences are not necessarily coexistent; for menstruation may occur without any such rupture; and, on the other hand, the maturation and discharge of mature ova may occur in the intervals of menstruation, and even at periods of life when that function is not taking place—as before the age of puberty;[5] and Dr. Ashwell[6] has related three cases in which he examined the ovaria of

[1] Bullet. de l'Académ. Royale de Méd., Jan., 1843.

[2] De la Puberté et de l'Age Critique chez la Femme, et sur la Ponte des Mammifères, &c., Paris, 1844.

[3] On the other hand, a case has been recently published by Mr. Godard, in which it appeared to him, from the phenomena observed after death, that in a first menstruation the sanguineous discharge had preceded, for a long time, the rupture of the ovarian vesicle; and he expresses the opinion that it alone may constitute the menstrual phenomenon. Comptes Rendus des Séances de la Société de Biologie, p. 110, Année 1854.

[4] London Medical Gazette, 1843; Lond. and Edinb. Monthly Journal of Med., Aug., 1845, or Amer. Journal of Med. Sciences, Oct., 1845, p. 431, and Jan., 1846, p. 185.

[5] The same view is maintained by Mr. Kesteven, London Medical Gazette, for Nov., 1849; see, also, Whitehead, On the Causes and Treatment of Abortion and Sterility, Amer. edit., p. 49, Philad., 1848.

[6] A Practical Treatise on the Diseases Peculiar to Women, 3d edit., Lond., 1848.

women, who had died during the menstrual flow, and in none was there the physical evidence of a maturated or rent Graafian vesicle; and he properly remarks, that it is by observation on the human female alone that the point can be settled. Moreover, it is important to bear in mind, in connexion with this subject, that although the discharge of ova may, and does, occur independently of sexual intercourse and excitement, M. Coste—as elsewhere remarked—has shown, that sexual intercourse may hasten their discharge, and he draws attention to what is observed in animals in the wild and in the domesticated state. In the former condition, "incessantly occupied with their own preservation, often exposed to the inclemency of the weather, and unable to procure sufficient nutriment, the functions of the ovaries are executed at rare intervals. But when they are sheltered in our dwellings, and are subjected to all the favourable conditions that domestication procures them, the maturation of ova may become so frequent that, with certain species, the *ponte* may be almost daily."[1] He has satisfactorily shown, also, that the recurrence of the period of heat is amazingly hastened by the presence and efforts of the male; and judiciously concludes:—"If, in birds, shelter, warmth, and nourishment can multiply the periods for the maturation and discharge of ova, and if in the mammalia the same causes, combined with the excitement of the male, are powerful enough to produce the same result, it would not be rational to suppose that the human species, which can be placed at its pleasure under all these conditions, and gathers around it all the benefits of civilization, should be inaccessible to these influences; and, by an inexplicable exception, should remain invariably restricted within the insurmountable limits of the menstrual periods. Such a supposition would be the more unreasonable, seeing—as I have already remarked—that woman has, and the females of the mammalia have not, the privilege of a permanent aptitude for sexual intercourse; and, consequently, the activity which the male influence can impress on the functions of her ovaries ought to be more intense than in the mammalia, in which such influence is much less direct, as it is reduced to simple efforts, that are resisted by the female."

The essential condition of menstruation would seem to be increased turgescence of the vessels of the uterus, and hypertrophy of the lining membrane, the morphology of which is analogous to that of the decidua of pregnancy. M. Coste[2] affirms, that he is possessed of twenty wombs of persons who were suicides, or died of some violent death, in which there was hypertrophy of the lining membrane of the uterus, the result of erethism; but in no case were there the floating villosities mentioned by Baer and E. Weber, or the pseudo-membranous exudation which may remain for at least two weeks described by almost all physiologists.

It has been much urged of late, as it was formerly, that there is a striking analogy between menstruation, and the *rut* or period of heat in animals; and so far as regards the maturation of ova, and the periodical secretion from the genital organs in the two conditions there

[1] Op. cit., p. 224. [2] Op. cit., p. 210.

may be ground for the analogy; but in other respects it is forced, and unsatisfactorily supported. Heat in animals means "*venereal heat*"—*ardor venereus*—and at that time only does the female admit the male; whilst the human female receives him at all times. It has been attempted, indeed, to show, that the human female, during menstruation, has the same increase of venereal ardour, and that the capability for impregnation is at this time at its acme; but this is not in accordance with exact observation.

That the aptitude is greater immediately after menstruation has been maintained since the time of Hippocrates.[1] It has been an old remark, too, that some are only capable of conception during the flow of the catamenia.[2] Müller,[3] Burdach,[4] and others, have denied the greater sexual feeling during the flow; and the author, after careful inquiry, has met with nothing to confirm it. *After* the menstrual period, it can be understood, that more feeling may exist, owing to sexual intercourse having been for a time interrupted; yet it would appear, that impregnation frequently occurs immediately *before* the last catamenial discharge. "The fact," says Dr. Carpenter,[5] "that conception often takes place *before* the last appearance of the catamenia (and not *after* it, as commonly imagined), is one well known to practical men." He is one of those who think "there is good reason to believe, that in women the sexual feeling becomes stronger at that epoch [the menstrual]; and "it is quite certain," he says, that "there is a greater aptitude for conception immediately *before* and *after* menstruation than there is at any intermediate period."

It would be strange, however, if the period of greatest aptitude for conception should be the one at which there is, and always has been, a repugnance to sexual union on the part of both sexes. Bischoff and Mr. Girdwood,[6] consider this repugnance as the result of habit, and the natural delicacy of the sex, rather than of actual disrelish; but this is by no means proved: on the contrary, facts would seem to establish the reverse. As confirmatory of the view, it has been affirmed by M. Raciborski[7]—who is, by the way, an ardent and enthusiastic observer—that the exceptions to the rule, that conception occurs immediately before, or immediately after, or during menstruation, are not more than six or seven per cent.; and that "of fifteen women, who specified accurately the period of their latest menstruation, as well as the dates of the connubial act, five conceived from coitus taking place from two to four days previous to the period at which the catamenial discharge was due; in seven, conception was dated from coitus occurring two or three days after menstruation; in two, it took place at the actual period of the catamenia; and in only one so long as ten days after." Even in

[1] De Naturâ Puer., cap. iii.; Pliny, Hist. Nat., sect. vii. lib. 18; Galen, De Semine, lib. i.

[2] Aristotle, Hist. Animal, lib. vii. cap. ii., Ambrose Paré, De Homin. Gener. liber. See, on all this subject, Prof. Litzmann, art. Schwangerschaft, Wagner's Handwörterbuch der Physiologie, 13te Lieferung, S. 47, Braunschweig, 1846, and Coste, op. cit., p. 190.

[3] Physiology, by Baly, p. 1482.

[4] Die Physiologie als Erfahrungswissenschaft, i. 250, 2te Auflage, Leipz., 1835.

[5] Op. cit.

[6] London Lancet, Dec. 7 and 14, 1844.

[7] London Lancet, Jan. 28, 1843, and in op. cit.

the exceptional case—we are told—the catamenia made their appearance shortly after the coitus, which took place at about the middle of the interval between the two regular periods.

These statements may be taken for what they are worth. Even if the facts were accurately observed, of which doubt may be entertained, they are numerically insufficient to enable any positive conclusions to be drawn: certainly, we are not sanctioned in inferring, that excepting within a short period before and after menstruation, the female is not likely to conceive, when—as before remarked—it has been sufficiently proved, that she is throwing off from the ovary infecund ova at other periods than the menstrual, and when there are unquestioned examples of fecundation resulting from a single coitus at an advanced stage of the intermenstrual period. All that we are perhaps justified in admitting, from recent observations, is, that there is a connexion between menstruation and the condition of the ovaries, regarding which, indeed, there ought to have been no doubt, as in a celebrated case of removal of both ovaries by Mr. Pott, menstruation entirely disappeared, although, previous to the removal, puberty existed, and the function had been well executed; and in disorganization of both ovaries the same thing has been observed;[1]—that ova are at this time, as at others, maturated and discharged into the Fallopian tubes;—and that changes occur in the lining of the uterus accompanied by a peculiar discharge;—the ovarian and uterine changes being simultaneous, and *perhaps* the latter being consequent on the former; but we have not approached, in the slightest degree, to a knowledge of the purpose served by the periodical catamenial secretion. If the periodical discharge of ova be menstruation, why is it, that the catamenial flow does not always accompany the maturation and discharge of ova?

The bearing of these views on impregnation and the formation of corpora lutea will be given hereafter.

The age, at which menstruation commences, varies in individuals and climates. It has been esteemed a general law, that the warmer the climate, the earlier the discharge takes place, and the sooner it ceases; but there is reason for doubting the correctness of this prevalent belief. With us, the most common period of commencement is from thirteen to seventeen years. Mahomet is said to have consummated his marriage with one of his wives, "when she was full eight years old."[2] Of 450 cases, observed at the Manchester Lying-in Hospital, in England,[3] menstruation commenced in the eleventh year in 10; in the twelfth in 19; in the thirteenth in 53; in the fourteenth in 85; in the fifteenth in 97; in the sixteenth in 76; in the seventeenth in 57; in the eighteenth in 26; in the nineteenth in 23; and in the twentieth in 4. Menstruation commonly ceases in the temperate zone at from forty to fifty years. These estimates are, however, liable to many exceptions, dependent upon individual differences. In rare cases, the catamenia have appeared at a very early age, even in childhood; and again, the menses with powers of fecundity have continued,

[1] Ashwell, A Practical Treatise on the Diseases peculiar to Women: Amer. edit. by Dr. Goddard, p. 49, Philad., 1845.

[2] Prideaux, Life of Mahomet, p. 30, London, 1718.

[3] Roberton, op. citat.

in particular instances, beyond the ages that have been specified: in some of these protracted cases the catamenia have been regular; in others, the discharge, after a long suppression, has returned. Of 77 individuals, they ceased in 1 at the age of 35; in 4 at 40; in 1 at 42; in 1 at 43; in 3 at 44; in 4 at 45; in 3 at 47; in 10 at 48; in 7 at 49; in 26 at 50; in 2 at 51; in 7 at 52; in 2 at 53; in 2 at 54; in 1 at 57; in 2 at 60; and in one at 70. Of 10,000 pregnant females, registered at the Manchester Hospital, 436 were upwards of 40 years of age; 397 from 40 to 45; 13 in their 47th year; 8 in their 48th; 6 in their 49th; 9 in their 50th; 1 in her 52d; 1 in her 53d; and 1 in her 54th. Mr. Roberton asserts, that as far as he could ascertain,—and especially in the three cases above 50 years of age,—the catamenia continued up to the period of conception.

The following table, founded on the results of 2352 cases, has been published by M. Brière de Boismont.[1] It will be seen, that by far the greatest number of women begin to menstruate during the 14th or 15th year.

Age.	Paris, 1200 cases by Meniers.	Paris, 85 cases by Marc D'Espine.	Lyons, 432 cases by Pétrequin.	Marseilles, 68 cases by Marc D'Espine.	Manchester, 450 cases by Roberton.	Göttingen, 137 cases by Osiander.
5	1	0	0	0	0	0
7	1	0	0	0	0	0
8	2	0	0	0	0	0
9	10	1	0	0	0	0
10	29	0	5	0	0	0
11	93	3	14	6	10	0
12	105	14	26	10	19	3
13	132	6	47	13	53	8
14	194	18	50	9	85	21
15	190	14	70	16	97	32
16	141	7	79	8	76	24
17	127	6	58	4	57	11
18	90	5	38	2	26	18
19	35	8	21	0	23	10
20	30	3	9	0	4	8
21	8	0	5	0	0	1
22	8	0	1	0	0	0
23	4	0	0	0	0	1
24	0	0	3	0	0	0

Dr. Guy[2] has furnished some valuable statistics in regard to the period at which the function commences and ceases amongst females in England. From observations on 1500 cases, it appeared, that the greatest number first menstruated at the age of 15; the 14th year came next in order; then the 16th; whilst the number at 13 and 17, at 12 and 18, and at 11 and 19, approximated very closely to each other. Before the 11th, and after the 19th year, the numbers were very small. In more than half the cases, menstruation made its first appearance at 14, 15, and 16 years of age. The earliest period was 8, and the latest 25. In regard to the period at which it ceases, he deduced from the results of 400 cases, that independently of disease, this might be at any period from the 27th to the 57th year. In the majority of cases it occurred

[1] De la Menstruation, &c., Paris, 1842.

[2] Medical Times, Aug. 9, 1845.

between 40 and 50 years,—the number from 45 to 50 being greater than that from 40 to 45 years.

Mr. Roberton[1] has attempted, and successfully, to show, that the age of puberty is about as early in the cold, as in the tropical regions of the earth; and, that were marriages to take place in England at as juvenile an age as they do in Hindostan, instances of very early fecundity would be as common in England as they are in that country. He is of opinion, that early marriage and early intercourse between the sexes, where found prevailing generally, "are to be attributed, not to any peculiar precocity, but to a moral and political degradation, exhibited in ill laws and customs, the enslavement more or less of the women, ignorance of letters, and impure or debasing systems of religion." He has also shown, from statistical evidence, that menstruation does not occur more early in the negress than in the white female; Dr. Vaigas, of Caraccas, indeed, in a letter to Professor Meigs, of Philadelphia, affirms, that precocious menstruation is more common in the white than in the coloured.[2]

It would seem, too, that when accurate investigations have been made, there is no striking difference between the age of puberty in the Esquimaux and in the women of Great Britain and this country. It is neither later owing to the rigour of the climate, nor earlier owing to race. Of 16 Esquimaux women, in regard to whom data on this subject were furnished to Mr. Roberton,[3] none menstruated under the age of 14; but, on the other hand, half the 16 Esquimaux menstruated under 16 years of age; whilst in corresponding data in regard to English women furnished by these observers, there was but one.

In the statement sent to Parliament by Bartholomew Mosse, when endeavouring to procure a grant for the Dublin Lying-in Hospital, he mentions, that 84 of the women delivered under his care were between the ages of 41 and 54; 4 of these were in their 51st year, and 1 in her 54th. A relation of Haller had two sons after her 50th year; and children are said to have been born even after the mother had attained the age of 60. A woman at Whitehall, New York, was delivered of a child at the age of 64.[4] Holdefreund relates the case of a female, in whom menstruation continued till the age of 71; Bourgeois till the age of 80; and Hagendorn till 90; it is probable, however, that these were not cases of true menstruation, but perhaps of irregularly periodical discharges of blood from the uterus or vagina. On the other hand, it may be remarked, that in the year 1828, a lady was a visitor at Ballston Springs, who was a grandmother, although only 28 years of age.[5] A case is, also, recorded of a female, who menstruated when one year old, and was pregnant at a little over 9. On the 20th of April, 1834, being 10 years and three days old, she was delivered of a child

[1] Edinburgh Med. and Surg. Journal, Oct., 1832, July, 1842, and July, 1845, p. 156; and London Med. Gazette, July 21, 1843.

[2] A Treatise on the Diseases and Special Hygiène of Females, by Colombat de l'Isère, translated by Dr. Meigs, p. 21, Philad., 1845.

[3] Edinburgh Medical and Surgical Journal; cited in London and Edinburgh Monthly Journal of Medical Science, March, 1845. p. 232.

[4] T. D. Mitchell, Western Lancet, Nov., 1846 p. 277.

[5] Mitchell, op. cit., p. 276.

weighing $7\frac{3}{4}$ lbs.[1] Sir George Simpson[2] states, that during his visit to Woahoo, a woman, twelve years of age, was living, "who had already presented to an English husband three thriving pledges of connubial love;" and the case of a young girl has been recorded by Mr. John Smith,[3] who began to menstruate when ten years and six months old, and was delivered of a child at 11 years and seven months.[4]

As a general rule, the appearance of the menses denotes the capability of being impregnated, and their cessation the loss of such capability, yet, as already remarked, females have become mothers without ever having menstruated. Foderé[5] attended a woman, who had menstruated but once—in her 17th year,—although 35 years of age, healthy, and the mother of five children. Morgagni instances a mother and daughter, both of whom were mothers before they menstruated. Sir E. Home[6] mentions the case of a young woman, who was married before she was seventeen, and, having never menstruated, became pregnant: four months after her delivery, she became pregnant again; and four months after the second delivery, she was a third time pregnant, but miscarried: after this she menstruated for the first time, and continued to do so for several periods, when she again became pregnant; and Mr. Harrison,[7] at a meeting of the Westminster Medical Society, remarked, that he knew an instance in which the mother of a large family had never menstruated;—yet Dr. Dewees[8] and Dr. Campbell[9] assert, that there is not a properly attested instance on record of a female conceiving previous to the establishment of the catamenia: the latter gentleman admits, however, that when an individual has once been impregnated, she may conceive again several times in succession, without any recurrence of the catamenia between these different conceptions,—because *he* has known a case of this kind, but not of the other!

During the existence of menstruation, the system of the female is more irritable than at other times; so that all exposure to sudden and irregular checks of transpiration should be avoided, as well as every kind of mental and corporeal agitation, otherwise the process may be impeded, or hysterical and other troublesome affections be excited. The sacred volume exhibits the feeling entertained towards the female, whilst performing this natural function. Not only was she regarded "unclean" in antiquity: she was looked upon, as Dr. Elliotson has remarked,[10] to be mysteriously deleterious. In the time of Pliny,[11] a menstruating female was considered to blight corn, destroy grafts and hives of bees, dry up fields of corn, cause iron and copper to rust and smell, drive dogs mad, &c., &c.; and it is firmly believed by many, that meat will not take salt if the process be conducted by one so circum-

[1] Transylvania Med. Journ., vii. 417; cited by Mitchell, op. cit.

[2] An Overland Journey round the World, Amer. edit., Part 2, p. 61, Philad., 1847.

[3] Lond. Med. Gaz., Nov. 3, 1848.

[4] Other cases are given in Taylor, Medical Jurisprudence, 3d Amer. from 4th Lond. edit., p. 440, Philad., 1853.

[5] Médecine Légale, i. 393, Paris, 1813.

[6] Philosoph. Transact., cvii. 258; and Lect. on Comp. Anatomy, iii. 298.

[7] London Lancet, Jan. 19, 1839, p. 619.

[8] Compend. System of Midwifery, 8th edit., Philad., 1836.

[9] Introduction to the Study of Midwifery, Edin., 1833.

[10] Elliotson's Blumenbach, p. 465; Lond., 1828.

[11] Histor. Natural., xxvii.

stanced. La Motte[1] had implicit belief in this opinion, and carried the absurdity so far as to assert, that red-haired women are worse than others in this respect: and he gives an anecdote of a red-haired servant of his who spoiled some choice wine, as he was about to sit down to enjoy it. He asserts positively, that the instant she touched the bottles, the wine was converted into vinegar,—much to the annoyance of himself and guests.

The temperature of the vagina does not appear to be affected by menstruation or pregnancy.[2]

c. *Sexual Ambiguity.*

The sexual characteristics, in the human species, are widely separate; and two perfect sexes are never united in the same individual. Yet such an unnatural union has been supposed to exist; from the fabulous son of Ἑρμης and Αφροδιτη,—Mercury and Venus,—to his less dignified representative of modern times:—

> "Nec fœmina dici,
> Nec puer ut possent, neutrumque et utrumque videntur."—*Ovid.*[3]

We have already remarked, that in the lower animals, and in plants, such hermaphrodism is common; but, in the upper classes, and especially in man, a formation that gives to an individual the attributes of both sexes has never been witnessed. Monstrous formations are occasionally met with; but if careful examination be made, it can usually be determined to what sex they belong. Cases, however, occur, in which it is difficult to decide, although we may readily pronounce, that the being is totally incapable of the function of reproduction. The generality of cases are produced by unusual developement of the clitoris in the female, or by a cleft scrotum in the male. Only two instances of the kind have fallen under the observation of the author, both of which were females, as they usually are. One of these has been described by the late Professor Béclard, of Paris, whose details we borrow.[4]

Marie-Madeleine Lefort, aged sixteen years, seemed to belong to the male sex, if attention were paid merely to the proportions of the trunk, limbs, shoulders, and pelvis; the conformation and dimensions of the pelvis; the size of the larynx; the tone of the voice; the developement of the hair; and the form of the urethra, which extended beyond the symphysis pubis. An attentive examination, however, of the genital organs showed, that she was of the female sex. The mons veneris was round, and covered with hair. Below the symphysis pubis was a clitoris, resembling a penis in shape, twenty-seven millimètres or about an inch long, in the state of flaccidity; and susceptible of slight elongation during erection; having an imperforate glans, hollowed beneath by a duct or channel, at the inferior part of which were five small holes situate regularly on the median line. Beneath and behind the clitoris,

[1] Traité des Accouchemens, p. 57.
[2] Fricke, Zeitschrift für die gesammte Medicin, Nov., 1838.
[3] "Both bodies in a single body mix,
A single body with a double sex."—*Addison.*
[4] Marc, art. Hermaphrodite, in Dict. des Sciences Médicales, xxi. 98, Paris, 1817.

a vulva existed, with two narrow, short and thin labia furnished with hair, devoid of anything like testicles, and extending to within ten lines of the anus. Between the labia was a superficial cleft, pressure upon which communicated a vague sensation of a void space in front of the anus. At the root of the clitoris was a round aperture, through which a catheter could not be passed into the bladder. It could be readily introduced, however, towards the anus, in a direction parallel to the perineum. When the catheter was passed a little backwards and upwards to the depth of eight or ten centimètres, it was arrested by a sensible obstacle; but no urine flowed through it. It seemed to be in the vagina. At the part where the vagina stopped, a substance could be distinguished through the parietes of the rectum, which seemed to be the body of the uterus. Nowhere could testicles be discovered. She had menstruated from the age of eight years; the blood issuing in a half coagulated state through the aperture at the root of the clitoris. She experienced, too, manifest inclination for the male, and a slight operation only would probably have been necessary to divide the apron, which closed the vulva from the clitoris to the posterior commissure of the labia. The urethra extended, in this case, for some distance beneath the clitoris, as in the penis; and from all the circumstances, M. Béclard concluded, that the person subjected to the examination of the *Société de Médecine* of Paris was a female; that she possessed several of the essential organs of the female,—the uterus and vagina,—whilst she had only the secondary characters of the male—as the proportions of the trunk and limbs, shoulders and pelvis; the conformation and dimensions of the pelvis; the size of the larynx; tone of the voice; developement of the hair; the urethra extending beyond the symphysis pubis, &c.

In the year 1818, a person was exhibited in London, who had a singular union of the apparent characteristics of both sexes. The countenance resembled that of the male, and there was a beard, but it was scanty. The shape, however, of the body and limbs was that of the female. The students of the Anatomical Theatre of Great Blenheim Street, London, of whom the author was one, offered her a certain sum, provided she would permit the sexual organs to be inspected by the veteran head of the school—Mr. Brookes: to this she consented. She was, accordingly, exposed before the class; and her most striking peculiarities exhibited. The clitoris was large, but not perforate. Mr. Brookes, desirous of trying an *experimentum crucis*, passed a catheter into the vagina, and attempted to introduce another into the urethra; but fearing discovery, and finding that the mystery of her condition was on the point of being unveiled, she started up and defeated the experiment. No doubt existed in the mind of Mr. Brookes, that there were two distinct canals,—one forming the vagina; the other the urethra,—and that she was, consequently, female.

One of the most complete cases of admixture of the sexes was described by Rudolphi before the *Academy of Sciences* of Berlin, at the sitting of October 22, 1825.[1] It was met with in the body of a child, which died, it was said, seven days after birth; but the developement

[1] American Journal of the Medical Sciences, p. 499, Feb., 1832.

of parts led to the supposition, that it was three months old. The penis was divided inferiorly; the right side of the scrotum contained a testicle; the left was small and empty. There was a uterus, which communicated at its superior and left portion with a Fallopian tube, behind which was an ovary destitute of its ligament. On the right side, there was neither Fallopian tube, nor ovary, nor ligament, but a true testicle, from the epididymis of which arose a vas deferens. Below the uterus was a hard, flattened ovoid body, which, when divided, exhibited a cavity with thick parietes. The uterus terminated above in the parietes of this body, but without penetrating its cavity. At its inferior part was a true vagina, which ended in a cul-de-sac. The urethra opened into the bladder, which was perfect; and the anus, rectum, and other organs were formed naturally. Rudolphi considered the ovoid body, situate beneath the uterus, to be the prostate, and vesiculæ seminales, in a rudimental state.

A curious case of doubtful sex was seen by Dr. Pue, of Baltimore. It occurred in a negro, who had the appearance of a woman, and passed for such. On examination, at the request of her owner, Dr. Pue found no signs of female organs of generation. There was a penis of some developement—the size of a boy's 12 or 14 years old. The glans was well formed, but the urethra did not terminate at the extremity of the organ. It opened at the frænum. There was some appearance of scrotum, but no testes were perceptible. Menstruation took place regularly, but with great pain, the fluid passing through the urethra. During this period, the breasts—which were natural, and of the size of a girl's of 14—became tender and swollen, and she had sexual desire at this time only. The pubes was well covered with hair. Dr. Pue's impression was, that her inclinations were for the male. A similar case has been described by Dr. S. H. Harris, of Clarksville, Virginia.[1]

Cases like the above,—and we have such on the authority of Baillie, Verdier, Giraud, Ackermann, Handy, Sir E. Home, Pinel, Maret, Sue, Bouillaud, and others,—have led to the belief, that hermaphrodism is possible. Such is the opinion of Tiedemann, Meckel, and others. The varieties of these sexual vagaries are extremely numerous; and occasionally form the subject of medico-legal inquiry. A singular case, in which a question of civil rights was involved, has been detailed by Dr. William James Barry.[2] At a warmly contested election in Connecticut, in the spring of 1843, a person named Suydam was brought forward as a voter, who was challenged by the opposite party, on the ground that he was more female than male, and that he partook of the attributes of both sexes. On examining him, Dr. Barry found the mons veneris covered with hair in the usual way; there was an imperforate penis, subject to erection, about two inches and a half long. It had a well formed glans, with a depression in the usual seat of the orifice of the urethra, and a well defined prepuce and foramen. The scrotum was not more than half the usual size, and not pendulous. In it, on the right side, was a testicle, of the size of a common filbert, with a spermatic cord. At the root of the corpora cavernosa in the perineum,

[1] American Journal of the Medical Sciences, for July, 1847, p. 121.
[2] New York Journal of Medicine, &c., Jan., 1847.

there was an aperture, through which the urine was discharged, large enough to permit the introduction of an ordinary sized catheter. From these appearances, Dr. Barry gave it as his opinion, that the person was a male citizen, and, consequently, entitled to vote. This decision was contested by Dr. Ticknor, who, however, after an examination, suggested by Dr. Barry, admitted, that Suydam was a male. He was accordingly allowed to vote; and the party ticket was carried by a majority of one. A few days after the election, Dr. Barry was informed, that Suydam had catamenia; and testimony was afforded, that he menstruated as regularly, but not as profusely, as most women. Drs. Barry and Ticknor now examined him together, with the following results. His height was five feet two inches; hair light coloured; complexion fair; chin beardless; temperament decidedly sanguineous; shoulders narrow; hips broad; and in short the figure was in all respects that of a female. The mammæ were well developed, with nipples and areolæ. On passing a female catheter into the opening through which the urine, as well as a monthly sanguineous flow, was discharged, the catheter, in place of entering the bladder, passed into a canal, similar to the vagina, three or four inches deep, in which the instrument had considerable play. Suydam stated, that he had erotic desires for the male sex, and his tastes and bodily powers resembled those of the female. It appeared, too, from proper testimony, that the aperture, through which the urine was discharged, was made by the accoucheur at the time of birth. Drs. Barry and Ticknor had, therefore, to renounce their previously expressed conviction that Suydam belonged to the male sex.

The case of an ourang-outang, described by Dr. Harlan,[1] affords as near an approach to a complete union of the sexes in the same individual as has been recorded. It had ovaries, Fallopian tubes, uterus, and vagina, and also testes, epididymis, vasa deferentia, and a highly erectile penis. Dr. Carpenter[2] states, that it is not certain, that the co-existence of testes and ovaria on the same side has ever been observed in the human species; yet a case has been described by Prof. Mayer,[3] of Bonn, in which the mixed attributes of male and female were well marked. On the one hand, there was a testicle slightly atrophied, a penis, and a prostate gland; on the other, a vagina and uterus with its Fallopian tubes; and, on the left side, a body analogous to an ovary. Dr. Blackman,[4] also, has recorded a singular case of admixture of sexes, which occurred to Dr. Ackley, of the Cleveland Medical College. It occurred in a person of large stature; external conformation, with the exception of the hips, male; beard moderate; penis large; scrotum of natural appearance, but empty; habits solitary, and disliking women; menstruation *per penem* monthly, attended with much suffering; and during one of these periods death occurred from cerebral congestion. The body was examined by Prof. Ackley. Fig. 430 will convey a good idea of the condition of the organs.

[1] Medical and Physical Researches, p. 22, Philad., 1835.

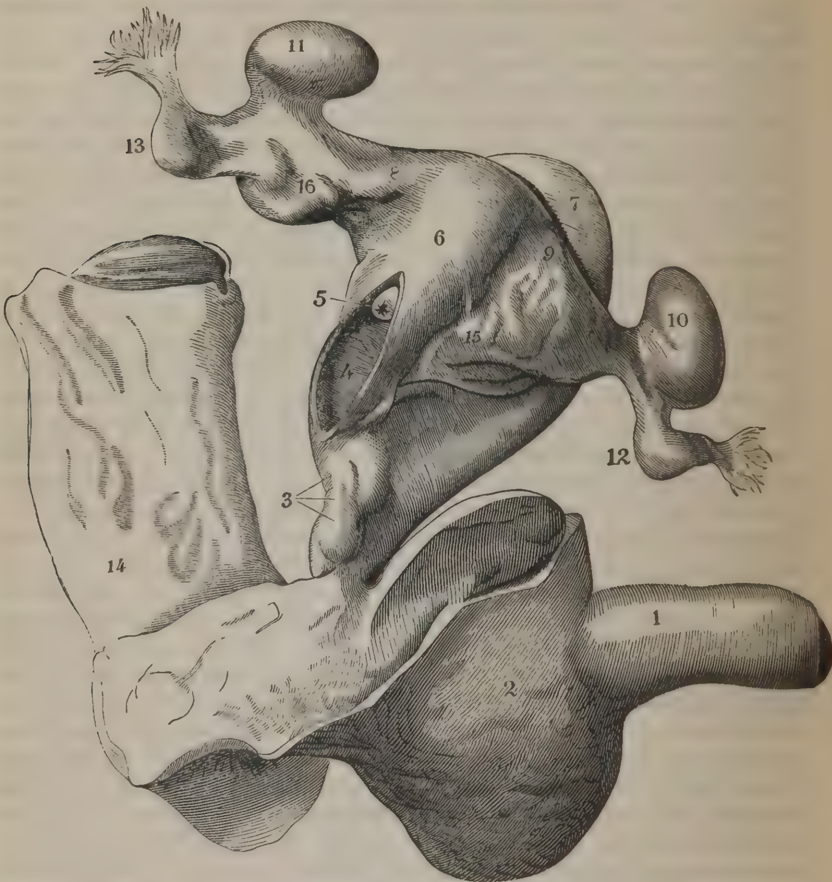
[2] Principles of Human Physiology, Amer. edit., p. 803, Philad., 1855. See, also, on this subject, Prof. Simpson, art. Hermaphroditism, in Cyclop. of Anat. and Physiol., ii. 684, London, 1839.

[3] Gazette Médicale de Paris, Sept. 24, 1836, and Philadelphia Med. Examiner, April 10, 1841, p. 232.

[4] Amer. Journal of the Medical Sciences, July, 1853, p. 66.

The vagina opened into the neck of the bladder, and thus communicated with the urethra. Its inner surface was reddened, and the

Fig. 430.



Hermaphrodism.

1. Male organ. 2. Scrotum, empty. 3. Prostate gland. 4. Vagina. 5. Os uteri. 6. Uterus. 7. Bladder. 8 and 9. Right and left Fallopian tubes. 10 and 11. Right and left testes. 12 and 13. Right and left ovaries. 14. Rectum. 15 and 16. Right and left vas deferens.

cavity contained menstrual blood. The Fallopian tubes were pervious, and the excretory ducts of the testes perfect. "Here, then," says Dr. Blackman, "we have an example of a monster with a testicle and ovary on each side; and with a prostate gland and uterus, the co-existence of which in the same being has been so flatly denied."

Monstrous productions, with a mixture of the male and female organs, seem to occur in neat cattle, and have been called *free-martins.* When a cow brings forth twin calves, one a male and the other apparently a female, the former always grows up to be a perfect bull; but the latter appears destitute of all sexual functions, and never propagates. This is the *free-martin.* It was the opinion of Mr. Hunter, that

it never exhibits sexual propensities; but this has been controverted by Mr. Allnatt.[1] A clergyman of great respectability informed him, that he had bred a free-martin upon his estate, which had not only shown a natural desire for the male, but had admitted him—of course, ineffectually. Mr. Allnatt farther remarks, that he had seen, the day before, working in harness, a true, apparently female, adult free-martin, which occasionally manifested its male propensities in an intelligible manner. When the cows amongst which this free-martin is kept, exhibit their inclination for the male, the creature—unlike the spayed heifer or common ox—is peculiarly on the alert, and has been observed to leap them like the entire male. A gentleman of Mr. Allnatt's neighbourhood had a true free-martin, which had received the bull several times, but had never propagated. After death the animal was examined. Scarcely a vestige of uterus could be discovered. From Mr. Hunter's observations[2] it would seem, that in all the instances of free-martins, examined by him, no one had the complete organs of the male and female, but partly the one and partly the other; and, in all, the ovaria and testicles were too imperfect to perform their functions. In noticing this phenomenon, Sir Everard Home[3] remarks, that it may account for twins being most commonly of the same sex: "and when they are of different sexes," he adds, "it leads to inquire, whether the female, when grown up, has not less of the true female character than other women, and is incapable of having children." "It is curious," says Sir Everard, "and in some measure to the purpose, that, in some countries, nurses and midwives have a prejudice, that such twins seldom breed." Dr. Burns, too,[4] states it to be a popular opinion, and he does not know any instance to discountenance it, that if twins be of different sexes the female is sterile. These remarks are singularly unfortunate, and ought not to have been hastily hazarded, seeing that a slight inquiry would have exhibited, that there is no analogy between the free-martin and the females in question; and, more especially, as the suggestion accords with a popular prejudice, highly injurious to the prospects, and painful to the feelings of all who are thus circumstanced. In the London Medical Repository,[5] Mr. Cribb, of Cambridge, England, has properly observed, that the external characters and anatomical conformation of the free-martin are totally unlike those of the human female. In external appearance, it differs considerably from the perfectly formed cow;—the head and neck, in particular, bearing a striking resemblance to those of the bull. Moreover, it is not true, that the free-martin cows never breed: Professor Simpson,[6] of Edinburgh, has referred to cases in which they were fecund. Mr. Cribb has, however, brought forward most decisive evidence in favour of the fallacy of the popular prejudice, by the history of seven cases, which are of themselves sufficient to put the matter for ever at rest. Of these *seven*, which are all that he had ever known, of

[1] London Medical Gazette for July 2d, 1836.

[2] Animal Œconomy, edit. by Mr. Owen, Amer. edit., p. 70, Philad., 1840.

[3] Philosoph. Transactions for 1799; and Lectures on Comparative Anatomy, iii. 311, London, 1823.

[4] Principles of Midwifery, edit. of 1843.

[5] Sept. 1823, and Ibid., 1827.

[6] Edinb. Med. and Surg. Journ., Jan., 1844, p. 109, and Obstetric Memoirs and Contributions, p. 314, Edinb., 1855.

women, born under the circumstances in question, having been married,—*six* had children. The fullest and most satisfactory essay on this subject is, however, the one already referred to by Professor Simpson. By uniting together all the various cases, which he could collect, he found that he possessed the married history of 123 females born co-twins with males. The results, so far as they refer to this subject, are as follows: of 123, 112 had families, and 11 no issue, although married for several years. In other words, the marriages of females, born under such circumstances, were infecund in the proportion of 1 in 10. From other investigations he deduced, that this proportion does not exceed the degree of unproductiveness of marriages in the general community; and from the whole of his inquiries he arrives at the following important conclusions. *First.* That in the human subject, females, born co-twins with males, are, when married, as likely to have children as any other females belonging to the general community. *Secondly.* That when they are married and become mothers, they are, in respect to the number of their children, as productive as other females; and *Thirdly.* That the same law of fecundity of the female in opposite-sexed twins seems to hold good amongst all the uniparous domestic animals, with the exception of the cow.

It is certainly strange, that this exception should apply to the cow only; and that when she carries twins of the same sex—two males, or two females—they should be in all cases perfectly formed in their sexual organization, and both be capable of propagating. The whole series of circumstances, when considered in conjunction with each other—as is well remarked by Professor Simpson—seems to form, in relation to the origin of malformations, one of the strangest and most inexplicable facts to be met with in the study of abnormous developement.[1]

2. PHYSIOLOGY OF GENERATION.

In man and the superior animals, in which each sex is possessed by a distinct individual, it is necessary that there should be a union of the sexes, and that the fecundating fluid of the male should be conveyed within the appropriate organs of the female, in order that, from the concourse of the matters furnished by both sexes, a new individual may result. To this union they are incited by an imperious instinct, established within them for the preservation of the species, as hunger and thirst are placed within them for the preservation of the individual. This has been termed the *desire* or *instinct of reproduction;* and for wise purposes its gratification is attended with the most pleasurable feelings, that man or animals can experience. Prior to the period of puberty, or whilst the individual is incapable of procreation, this desire does not exist; but it suddenly makes its appearance at puberty; persists vehemently during youth and the adult age, and disappears in advanced life, when procreation becomes again impracticable. It is strikingly exhibited in those animals, in which generation can only be effected at

[1] See on the subject of Hermaphrodism, Prof. Simpson, art. Hermaphroditism, in op. cit., Marc, art. Hermaphrodite, op. cit., and J. G. St. Hilaire, Histoire Générale et Particulière des Anomalies de l'Organisation, ii. 23, Bruxelles, 1837; also, Taylor, Medical Jurisprudence, Amer. edit., by Dr. E. Hartshorne, p. 425, Philad., 1853.

particular periods of the year, or whilst they are in *heat*;—as in the deer, during the *rutting* season.

The views that have been entertained regarding the seat of this instinct—whether in the encephalon or genital organs—are considered under the head of the mental and moral manifestations. It is there stated, that MM. Cabanis and Broussais consider, that internal impressions proceed from the genital organs, and form part of the psychology of the individual; and that Gall assigns an encephalic organ—the cerebellum—for their production, ranking the instinct of reproduction amongst the primary faculties of the mind,—with what degree of truth, is there investigated. In many cases, the desire is produced through the agency of vision; when the brain must necessarily be first excited, and, through its influence, the generative apparatus. Its immediate cause has been ascribed by some, to the presence of sperm, in the requisite quantity, in the vesiculæ seminales; but in answer to this, it is urged, that eunuchs under the circumstances above mentioned, and females, in whom there is no spermatic secretion, have the desire. The fact is, we have no more precise knowledge of the nature of this instinct, than we have of any of the sensations or moral faculties. We know, however, that it exhibits itself in various degrees of intensity, and occasionally assumes an opposite character—constituting *anaphrodisia*.

a. *Copulation.*

In the union of the sexes, the part performed by the *male* is the introduction of the penis,—the organ for the projection of the sperm towards the uterus,—and the excretion of that fluid during its introduction. In the flaccid state of the organ penetration is impracticable; it is first of all necessary, that under the excitement of venereal desire the organ should attain a necessary degree of rigidity, which is termed *erection*. In this state it becomes enlarged, and raised towards the abdomen; its arteries beat forcibly; the veins are tumid; the skin is more coloured, and the heat augmented. It becomes also of a triangular shape, and these changes are indicated by an indescribable feeling of pleasure. Erection is not dependent upon volition. At times, it manifests itself against the will; at others refuses to obey it; yet it requires, apparently, the constant excitement of the encephalic organ concerned in its production,—the slightest distraction of the mind putting an end to it. The modest and retiring spouse is, at times, unable to consummate the marriage for nights, perhaps weeks; yet, he is only temporarily impotent; for the inclination and consequent erection supervene sooner or later. Pills of crumb of bread, and a recommendation to the individual not to approach his wife for a fortnight, whatever may be his desire, have, in almost all cases, removed the impotence.

The state of erection is not long maintained, except under unusual excitement;—the organ soon returning to its ordinary condition of flaccidity. Its cause is a congestion of blood in the erectile tissue of the corpora cavernosa, urethra, and glans. Swammerdam and De Graaf cut off the penis of a dog during erection, and found the tissue gorged with blood, and that the organ returned to its flaccid condition

as the blood flowed from it. The same fact, according to M. Adelon,[1] has been observed in the human subject, when erection has continued till after death. The author's late friend, Mr. Callaway,[2] of Guy's Hospital, London, has described the case of an individual, who, in a state of inebriation, had communication three times with his wife the same night, without the consequent collapse succeeding, although emission ensued each time. This state persisted for sixteen days, notwithstanding the use of appropriate means; at this time, an opening was made with a lancet into the left crus of the penis, below the scrotum; when a large quantity of dark, grumous blood, with numerous small coagula, escaped. By pressing the penis, the corpora cavernosa were immediately emptied, and each side became flaccid,—the communication by the pecten or septum penis permitting the discharge of the contents of both corpora by the incision. After recovery, the person remained quite impotent, the organ being incapable of erection,—probably owing, as Mr. Callaway suggests, to the deposition of coagulable lymph in the cells of the corpora cavernosa preventing the admission of blood, and the consequent distension of the organ. Artificial erection can, likewise, be induced in the dead body by injections, so that but little doubt need exist, that the enlargement and rigidity of the penis during erection are caused by the larger quantity of blood sent into it. The difficulty has been to account for this increased flow. The older writers ascribed it to the compression of the internal pudic vein against the symphysis pubis, owing to the organ being raised towards the abdomen by the ischio-cavernosi muscles; and as the cavernous vein empties its blood into the internal pudic, stagnation of blood in the corpora cavernosa ought necessarily to result from such compression, and consequent distension of the organ; whilst the cavernous arteries, being firmer, could not yield to the compression, and would, therefore, continue to convey blood to the penis. It is obvious, however, that here,—as in every case, where the erectile tissue is concerned,—the congestion must be of an active kind; the beating of the arteries and the coloration of the organ indicate this; and, besides, compression of the pudic vein cannot precede erection; it must, if it occurs at all, be regarded rather as a consequence of erection than as its cause. The case of the nipple of the female affords us an instance of erectility, where no compression can be invoked, and where the distension must be caused by augmented flow of blood by the arteries. If the nipple be handled, particularly whilst she is under voluptuous excitement, it enlarges, and becomes rigid, or is in a true state of erection. The correct opinion seems to be, that irritation of this erectile tissue is the first link in the chain of phenomena constituting erection. The feeling of pleasure is certainly experienced there, prior to, and during erection; and this irritation, like every other, solicits an increased flow of blood into the erectile tissue, which, by organization, is capable of considerable distension. The erectile tissues of the corpora cavernosa, corpus spongiosum urethræ, and glans, are concerned in the process; but in what precise manner physiologists are not entirely agreed. Some have supposed,

[1] Physiologie de l'Homme, edit. citat., iv. 57.
[2] London Medical Repository, for April, 1824.

that the blood is effused into the cells, and is consequently out of the vessels. Another view, supported by certain eminent anatomists and physiologists, is, that the blood simply accumulates in the venous plexuses of the corpora cavernosa. Such seems to have been the opinion of Tiedemann, Stieglitz, and J. Müller,[1] and of Cuvier, Chaussier, and Béclard, from their injections; and the rapidity, with which erection disappears, favours the notion. The discovery of the helicine arteries of the penis by Professor Müller, described at page 577, has led to the inference that the peculiar arrangement may be concerned in the function in question, but in what manner the circulation in the male organ, or its erection, is modified by them has not been determined; Valentin, indeed,—as we have seen,—denies their existence.

It has been asked again, whether this accumulation of blood be, as we have remarked, an increased afflux by the arteries, or a diminished action of the veins; or these two states combined. The last opinion is probably the most correct. The arteries first respond to the appeal; the organ is, at the same time, raised by the appropriate muscles; its tissue becomes distended; the plexus of veins turgid, and the return of blood impeded. In this way, the organ acquires the rigidity necessary for penetrating the parts of the female. The friction, which then occurs, keeps up the voluptuous excitement, and the state of erection. This excitement is extended to the whole generative system; the secretion of the testicles is augmented; the sperm arrives in greater quantity in the vesiculæ seminales; the testicles are drawn up towards the abdominal ring by the contraction of the dartos and cremaster, so that the vas deferens is rendered shorter, and, in the opinion of some, the sperm filling the excretory ducts of the testicle is in this manner forced mechanically forwards towards the vesicles. When these have attained a certain degree of distension, they contract suddenly and powerfully, and the sperm is projected through the ejaculatory ducts into the urethra. At this period, the pleasurable sensation is at its height. When the sperm reaches the urethra, the canal is in the highest degree of excitement; and the ischio-cavernosi and bulbo-cavernosi muscles, with the transversi perinei, and levatores ani, are thrown into violent contraction; the first two holding the penis straight, and assisting the others in projecting the sperm along the urethra. By the agency of these muscles and of the proper muscular structure in the urethra, the fluid is expelled, not continuously, but in jets, as it seems to be sent into the urethra by the alternate contractions of the vesiculæ seminales. These muscular contractions are of a reflex character, being independent of the will, and incapable of being controlled by any exertion of it. They are induced, as in deglutition, by a special excitant,—the sperm in one case; the food in the other.[2]

The quantity of sperm discharged varies materially according to the circumstances previously mentioned; its average has been estimated at about two drachms. Along with the true sperm, the fluids of the prostate and glands of Cowper are discharged; so as to constitute the

[1] Art. Erection, in Encyclop. Wörterb. der Medicin. Wissenschaft., xii. 460, Berlin, 1834.

[2] For an elaborate inquiry into the physiology of erection, see Béraud, Manuel de Physiologie de l'Homme, pp. 385–400, Paris, 1853.

semen as we meet with it. When the emission is accomplished, the penis gradually returns to its ordinary state of flaccidity; and it is usually impracticable, by any effort, to repeat the act without the intervention of a certain interval of repose, to enable the due quantity of sperm to collect in the spermatic vessels and vesicles. In some persons, however, the excitability is so great, and the secretion so ready, that little or no interval is required between the first and second acts. A singular case of satyriasis, well observed by Mr. Norris, of London, is recorded by him in the Latin language.[1] For two months the man had intercourse with his wife, according to his and her testimony, fifteen times each night, and occasionally twenty times, and always with emission!

This comprises the whole of the agency of the male in the function of generation.

In man, the emission of sperm is soon effected; but in certain animals it is a long process. In the dog, which has no vesiculæ seminales, the penis swells so much, during copulation, that it cannot be withdrawn until the emission of sperm removes the erection.

In the *female*, during copulation, the clitoris is in the same state of erection as the penis; so is the spongy tissue lining more especially the entrance of the vagina; and it is in these parts, particularly in the clitoris, that pleasure is experienced during sexual desire, and copulation. This feeling persists the whole time of coition, and ultimately attains its acme, as in the case of the male, but without any spermatic ejaculation. It is not owing to the contact of the male sperm,—for it frequently occurs before or after emission by the male, but is dependent upon some inappreciable modification in the female organs,—in the ovaries or Fallopian tubes, it is supposed by some physiologists. In most—if not in all—cases, an increased discharge suddenly takes place, during the orgasm, from the mucous follicles of the vagina and vulva, but chiefly from the glands of Duverney, the admixture of which with the male sperm is supposed to have some connexion with impregnation, and to be, perhaps, the vehicle for the fecundating principle of the sperm. After the kind of convulsive excitement into which the female is thrown, a sensation of languor and debility is experienced, as in the male,—but not to the same extent;—and, in consequence of no spermatic emission taking place in her, she is capable of a renewal of intercourse more speedily, and can better support its frequent repetition.

The comparative degree of voluptuous excitement experienced by the male and female during sexual union has been an oft agitated question. It is of course impracticable to arrive at any positive or even approximative decision. Kobelt[2] expresses the opinion, that the great size of the bulbi vestibuli (Fig. 414), and the energetic compression they experience from the male organ; and especially the vast amount of nerves concentrated in so small a space, joined to her great general sensibility are ample reasons for inferring that the part of the female in the act is more considerable.

[1] Transactions of the Medical Society of London, vol. i. part i. p. 176, Lond., 1810.

[2] De l'Appareil du Sens Génital des deux Sexes, traduit de l'Allemand, par H. Kaula, D. M., p. 116, Strasbourg & Paris, 1851.

b. *Fecundation.*

An admixture having, in this manner, been effected between the materials furnished by the male and female,—after a fecundating copulation *conception* or *fecundation* results, and the rudiments of the new being are instantaneously constituted. The well-known fact, that, after the removal of the testicles, the individual is incapable of procreation although the rest of the genital organs may remain entire, is of itself sufficient to show, that the fecundating fluid is the secretion of those organs, and that this fluid is indispensable. Physiologists have not, however, been satisfied with a knowledge of this fact. Spallanzani[1] examined frogs with great attention, whilst in the act of copulation, both in and out of water; and he observed, that, at the moment when the female deposits her eggs, the male darts a transparent liquid through a tumid point which issues from its anus. This liquid moistens the eggs, and fecundates them. To be certain that it is the fecundating agent, he dressed the male in waxed taffeta breeches; when he found, that fecundation was prevented, and sperm enough was contained in the breeches to be collected. This he took up by means of a camel's-hair pencil, and all the eggs which he touched with it were fecundated. Three grains of the sperm were sufficient to render a pound of water fecundating; and a drop of a solution, which could not contain more than the 2,994,687,500th part of a grain, was enough for the purpose. To diminish the objection, that the frog is too remote in organization from man to admit of any analogical deduction, Spallanzani took a spaniel bitch, which had engendered several times; shut her up some time before the period of *heat*, and waited until she exhibited evidences of being in that condition, which did not happen until after a fortnight's seclusion. He then injected into the vagina and uterus, by means of a common syringe warmed to 100° of Fahrenheit, nineteen grains of sperm obtained from a dog. Two days afterwards, she ceased to be in heat, and, at the ordinary period, brought forth three young ones, which not only resembled her but the dog from which the sperm had been obtained. This experiment has been repeated by Rossi, of Pisa, and Buffolini, of Cesena, with similar results.[2] The success of an analogous experiment on the human species rests on the authority of John Hunter. He recommended an individual, affected with hypospadias, to inject his sperm through a warm syringe. His wife became pregnant.[3]

In some experiments on generation, MM. Prévost and Dumas fecundated artificially the ova of the frog. Having expressed the fluid from several testicles, and diluted it with water, they placed ova in it. These were observed to become tumid and developed; whilst other ova, placed in common water, merely swelled up, and in a few days became putrid. They observed, moreover, that the mucus, with which the ova are covered in the *oviduct*,—the part corresponding to the Fallopian tube in the mammalia,—assists in the absorption of the sperm, and in conducting it to the surface of the ovum; and that in

[1] Sur la Génération, par Senebier, Genèv., 1783.
[2] Adelon, Physiologie de l'Homme, iv. 66, Paris, 1829.
[3] Sir E. Home, Lect. on Comp. Anat., iii. 315.

order to succeed in these artificial fecundations, the sperm must be diluted; if too much concentrated its action is less. They satisfied themselves likewise, that the chief part of the sperm penetrates as far as the ova, as animalcules could be detected moving in the mucus covering their surface, and these animalcules, they conceive, are the active part of the sperm. It is not, however, universally admitted, that positive contact of sperm with the ovum is indispensable to fecundation. Some physiologists maintain, that the sperm proceeds no further than the upper part of the vagina; whence it is absorbed by the vessels of that canal, and conveyed through the circulation to the ovary. This is, however, the most improbable of all the views that have been indulged on this topic; for if such were the fact, impregnation ought to be effected as easily by injecting sperm into the blood-vessels,—the female being, at the time, in a state of voluptuous excitement. It has been directly overthrown, too, by the experiments of Dr. Blundell[1] on the rabbit, who found, that when the communication between the vagina and the uterus was cut off, impregnation could not be accomplished, although the animal admitted the male as often as fifty times, generally at intervals of two or three days or more. Yet it was evident that much of the male fluid had been deposited in the vagina, and absorbed by veins or lymphatics.[2] Bischoff[3] states, that he has frequently extirpated the uterus in rabbits, leaving the vagina and ovaries with the tubes; and in no case was the animal fecundated after the operation, although it admitted the male freely.

Others have presumed, that when the sperm is thrown into the vagina, a *halitus* or *aura—aura seminis*—escapes from it, makes its way to the ovary, and impregnates an ovum; whilst others, again, are of opinion, that the sperm is projected into the uterus, and in this cavity undergoes admixture with the germ furnished by the female; and a last class, with more probability in their favour, maintain, that the sperm is thrown into the uterus, whence it passes through the Fallopian tube to the ovary, by the fimbriated extremity of the tube embracing at the time the latter organ. Dr. Dewees[4] suggested, that after the sperm is deposited on the labia pudendi or in the vagina, it may be taken up by a set of vessels—which, he admitted, had never been seen in the human female—whose duty it is to convey it to the ovary. This conjecture, he conceived, had been in part confirmed by the discovery of ducts, leading from the ovary to the vagina, in the cow and sow, by Dr. Gartner, of Copenhagen. The objections that may be urged against his hypothesis, Dr. Dewees remarks, "he must leave to others." We have no doubt, that his intimate acquaintance with the subject could have suggested many that are pertinent and cogent. It will be obvious, that if we admit the existence of the ducts described by Gartner, it by no means follows, that they are inservient to the function in question. Independently, too, of the objection, that they have not been met with in the human female, it may be urged,

[1] Principles and Practice of Obstetricy, Amer. edit., Washington, 1834.

[2] See the details of an experiment with a similar object by Harlan, Medical and Physical Researches, p. 627, Philad., 1835.

[3] Développement de l'Homme, &c., traduit par Jourdan, p. 20, Paris, 1843.

[4] A Compendious System of Midwifery, 7th edit., Philad., 1835.

that if we grant their existence there would seem to be no reason, why closure of the os uteri after impregnation, or interruption of the vulvo-uterine canal by division of the vagina—as in the experiments of Dr. Blundell on rabbits—or division of the Fallopian tubes, should prevent subsequent conception,—in the first case during the existence of pregnancy,—in the last two for life. These vessels ought, in both cases, to continue to convey sperm to the ovary; and extra-uterine pregnancies or superfœtation ought to be constantly occurring.

MM. Prévost and Dumas,[1] and Dr. Ritchie,[2] are amongst the most recent writers, who maintain, that fecundation takes place in the uterus, and the former gentlemen assign the following reasons for their belief. *First.* In their experiments, they always found sperm in the cornua of the uterus, and they conceive it natural, that fecundation should be effected only where sperm is. *Secondly.* In animals, whose ova are not fecundated until after they have been laid, fecundation must necessarily be accomplished out of the ovary; and, *Thirdly.* In their experiments on artificial fecundation, they have never been able to fecundate ova taken from the ovary. In reply to the first of these positions it has been properly remarked by M. Adelon,[3] that the evidence of MM. Prévost and Dumas with regard to the presence of sperm elsewhere than in the uterus is only of a negative character; and that, on the other hand, we have the positive testimony of physiologists in favour of its existence in the Fallopian tubes and ovary. Haller asserts, that he found it there; and MM. Prévost and Dumas afford us evidence against their position respecting the seat of fecundation. They affirm, that on the first day after copulation, sperm was discoverable in the cornua of the uterus, and it was not until after the lapse of twenty-four hours, that it had attained the summits of the cornua. Once they detected it in the Fallopian tubes;—a circumstance, which is inexplicable under the view, that fecundation is accomplished in the uterus. Leeuenhoek and Hartsöker, also, found it in some cases in the Fallopian tube; and Bischoff, Wagner,[4] and Dr. M. Barry[5] discovered spermatozoids in the fluid collected from the surface of the ovary, and within the capsular prolongations of the Fallopian tubes that enclose the ovaries. Still more recently, Dr. Barry,[6] in two cases, found spermatozoids within an ovum of the rabbit taken from the Fallopian tube. They were within the thick transparent membrane—*zona pellucida*—brought with the ovum from the ovary; and it will be shown presently, that the positive penetration of the ovum by the spermatozoids has been confirmed by other observers. M. Pouchet,[7] however, whilst he gives delineations of spermatozoids found in the middle of the Fallopian tubes of a rabbit on the surface of an ovum fifteen hours after copulation, denies that in the mammalia the sperm can ascend to the ovary. The contractions of the tubes; their ciliary movements; the capillarity of the ducts, and the impassable mucus (*mucus infranchis-*

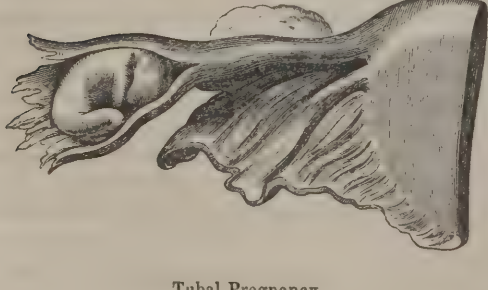
[1] Annales des Sciences Naturelles, iii. 113.
[2] Lond. Med. Gazette, cited in Amer. Journ. of the Med. Sciences, Jan., 1846, p. 187.
[3] Physiologie de l'Homme, 2de édit., iv. 68, Paris, 1829.
[4] Elements of Physiology, translated by Dr. R. Willis, p. 66, Lond., 1841.
[5] Philosophical Transactions for 1839, p. 315.
[6] Proceedings of the Royal Society, Dec. 8, 1842.
[7] Théorie Positive de l'Ovulation Spontanée, Atlas, Planche xv. fig. 9, Paris, 1847.

sable) he regards as invincible impediments; and maintains, categorically,—or, to employ the language of M. Raciborski,[1] cited by M. Pouchet himself, "with a vigour and energy of dialectics hitherto unused in science," that "even if it could reach the germiferous organ, it assuredly could not traverse the thick coats, which protect the ovules and arrive at them."[2] He believes, moreover, that observers must have taken for spermatozoids on the ovary certain moving bodies, which he calls *pseudo-zoo-spermes*, and which, he says, can only be either microscopic entozoa, or the extremities of certain of the digitations, which form the fimbriated extremity of the Fallopian tube,—more probably the latter.[3] He admits, however, that it seems to be almost certain, that these *pseudo-zoo-spermes* are exactly the same bodies as were seen by M. Donné,[4] on the nasal mucous membrane of a man. M. Donné observed epithelial shreds of this membrane separate spontaneously into minute conical portions, each of which had its own movement, like that of the spermatozoids; and we have elsewhere shown,—contrary to the opinion of M. Pouchet,—that the spermatozoids themselves are not perhaps entitled to any higher rank than that of ciliated epithelial cells.

In reply to the second argument, it may be remarked, that analogies drawn from inferior animals are frequently loose and unsatisfactory; and ought, consequently, to be received with caution. This is peculiarly one of those cases; for fecundation, in many animals, is always accomplished *out* of the body; and analogy might with equal propriety be invoked to prove, that in the human female the same thing must occur. Moreover, in certain oviparous animals—as in the common fowl—a single intercourse with the male may fecundate all the eggs she may lay in a season. In answer to the third negative position of MM. Prévost and Dumas, the positive experiments of Spallanzani may be cited, who succeeded in producing fecundation in ova that had been previously separated from the ovary.

The evidence that conception—as the rule—takes place in the ovary, appears to be convincing. Ovarian pregnancy offers proof of it. Of this, Mr. Stanley, of Bartholomew's Hospital, has given an instructive example;[5] and a still more extraordinary one is related by Dr. Granville.[6] Other varieties of extra-uterine pregnancy are confirmative of the same position. At times, the fœtus is found in the cavity of the abdomen,—the ovum seeming to have escaped from the Fallopian tube when its fimbriated extremity grasped the ovary to re-

Fig. 431.



Tubal Pregnancy.

[1] De la Puberté et de l'Age Critique, p. 519, Paris, 1844.
[2] Op. cit., p. 449.
[3] Op. cit., p. 416.
[4] Cours de Microscopie, p. 175, Paris, 1844.
[5] Medical Transactions, vol. vi.
[6] Philosophical Transactions for 1820.

ceive and convey it to the cavity of the uterus. At other times, the fœtus is developed in the Fallopian tube,—as in the marginal figure (Fig. 431),—some impediment having existed to the passage of the ovum from the ovary to the uterus. This impediment can be excited artificially, so as to give rise to tubal pregnancy. Nuck applied a ligature around one of the cornua of the uterus of a bitch, three days after copulation; and found, afterwards, two fœtuses arrested in the Fallopian tube between the ligature and ovary. Von Baer[1] detected an ovule in its passage along the Fallopian tube in a bitch; and Raspail asserts, that he once met with an ovule still attached to the ovary, which contained an embryo.[2]

It is obvious, then, from these facts, either that fecundation occurs in the ovary, or else that the ovum, when fecundated in the uterus, travels along the Fallopian tube to it; and thence back again to the uterus, which is not probable. It has been said, indeed, that ovarian and tubal pregnancies are exceptions to the rule; but no adequate evidence has been afforded of this. They certainly establish, that fecundation does take place in the ovary, and we are in want of positive, well authenticated cases of its having been accomplished elsewhere. To this conclusion M. Coste—who formerly was of opinion that fecundation is effected normally in the Fallopian tube, and probably about its middle—has come of late. He frankly declared to the French Institute, that the result of his recent experiments had led him to renounce his former opinion, and to embrace that of the ancients, who placed the seat of fecundation in the ovary.[3]

But, to prevent impregnation, it is not necessary that the ovaries should be removed. It is sufficient to deprive them of all immediate communication with the uterus, by simply dividing the Fallopian tubes. On this subject, Dr. Haighton[4] instituted numerous experiments, the result of which was, that after the operation a fœtus was in no instance produced. The operation is much more simple than the ordinary method of spaying by the removal of the ovaries, and it has been successfully practised, at the recommendation of the author, on the farm of his friend, Thomas Jefferson Randolph, Esq., of Virginia. Simple division of the Fallopian tubes does not take away the sexual desire, as Haighton supposed; for the ovaries are still existent; but if they be removed, all desire is lost. A case is detailed of a natural defect of this kind in an adult woman, who had never exhibited the slightest desire for commerce with the male, and had never menstruated. On dissection, the ovaries were found deficient; and the uterus was not larger than an infant's.[5] Dr. Blundell has proposed the division of the tubes, and even the removal of a small portion of them, so as to render them completely impervious, when the pelvis is so contracted as not to admit of the birth of a living child in the seventh month; and he goes so far as to affirm, that the operation is much less dangerous than delivery by perforating the head, when the pelvis is greatly contracted.

We have already remarked, that sperm has been found in the cavity

[1] De Ovi Mammalium et Hominis Genesi, Lips., 1827.
[2] Chimie Organique, p. 262, Paris, 1833.
[3] Béraud, Manuel de Physiologie de l'Homme, &c., p. 439, Paris, 1853.
[4] Philosoph. Transact. for 1797.
[5] Philosoph. Transact. for 1805.

of the uterus, and even in the Fallopian tubes. Fabricius ab Acquapendente maintained, that it could not be detected there; and Harvey contended, that in the case of the cow, whose vagina is very long, as well as in numerous other animals, it cannot possibly reach the uterus, and that there is no reason for supposing it ever does. In addition, however, to the facts already cited, we may remark, that Mr. John Hunter[1] killed a bitch in the act of copulation, and found the semen in the cavity of the uterus, conveyed thither, in his opinion, *per saltum*. Ruysch[2] discovered it in the uterus of a woman taken in adultery by her husband and killed by him; and Haller[3] in the uterus of a sheep killed forty-five minutes after copulation. An interesting case, in relation to this point, was published by Dr. Henry Bond,[4] of Philadelphia. A young woman, after having passed a part of the night with a male friend, destroyed herself early in the morning, by taking laudanum. On cutting open the uterus, it was found to be thickly coated with a substance having the appearance, and strong peculiar odour of sperm. One of the Fallopian tubes was laid open, and found to contain apparently the same matter; but it was not ascertained whether it possessed the seminal odour. More recently, Bischoff,[5] in his investigations, found few or no spermatozoids in the vagina of bitches and rabbits, after coitus; but the uterus was quite full of them.

This favours the view of Blumenbach,[6] who supposes, that during the venereal orgasm, the uterus sucks in the sperm. It is impossible to explain the mode in which this is accomplished, but the fact of the entrance of the fluid into that organ, and even as far as the ovary, seems unquestionable. This Dr. Blundell[7] admits, but he is disposed to think, that, in general, the rudiments from the mother, and the fecundating fluid meet in the uterus; as, in his experiments on rabbits, he found—from the formation of corpora lutea, the developement of the uterus, and the accumulation of water in the uterine cavity—that the rudiments may come down into the uterus, without a previous contact with the sperm. His experiments, however, appear to prove nothing more, than that infecund ova may be discharged from the ovarium; and that if they are prevented from passing externally, owing to closure of the vagina or cervix uteri, the uterine phenomena alluded to may occur. They do not invalidate the arguments already brought forward to show, that the ovum must be fecundated in the ovarium.

It has been suggested by Dr. Bostock,[8] that the ciliary motions, which have been observed by Purkinje, Valentin,[9] and others, on the

[1] Philosoph. Transact. for 1817.

[2] Thesaur. Anat. iv.; and Adversaria Anat. Med.-Chirurg., Dec. 1.

[3] Element. Physiol., viii. 22.

[4] American Journal of the Medical Sciences, No. xxvi., February, 1834, p. 403.

[5] Entwickelungsgeschichte des Kaninchen-Eies, u. s. w., Leipz., 1842; cited by Mr. T. W. Jones, in Brit. and For. Med. Rev., Oct., 1843, p. 513: and Op. cit. Also, E. Thomas, Die Physiol. des Menschen, S. 52, Leipz, 1853; and J. Béclard, Traité Élémentaire de Physiologie, p. 866, Paris, 1855.

[6] Elements of Physiology, by Elliotson, 4th edit., p. 467, Lond., 1828. See, also, Günther, Untersuchungen und Erfahrungen, Hannover, 1837, cited by Bischoff.

[7] Principles, &c., of Obstetricy, Amer. edit., p. 56, Washington, 1834.

[8] Physiology, 3d edit., p. 654, Lond., 1836.

[9] Müller's Archiv., B. i.; and translation in Dublin Journal of Med. Science, May, 1835; and in Edinb. New Philos. Journal, for July, 1835.

mucous membrane of the air-passages, and likewise on that of the generative organs, and whose office appears to be to propel substances along them, may have something to do with the propulsion of the sperm towards the ovary; and J. Müller[1] affirms, that "the mode in which the semen is conducted so far through the female generative organs, is no longer a problem requiring solution; for the discovery of the ciliary motion affords a solution of it." Dr. Sharpey,[2] however, remarks, that the direction of these motions is from within outwards, so that he conceives it to be difficult to assign any other office to them than that of conveying outwards the secretion of the membrane; unless we suppose that they also bring down the ovum into the uterus. Prof. Wagner[3] considers that the sperm reaches the ovary, partly by ciliary motion, which begins in the cervix uteri, partly by the contraction of the tubes, and partly by the motility of the spermatozoids; whilst Dr. Carpenter[4] thinks it not unreasonable to suppose, that the last is the sole power; and that the transit of the spermatozoids from the vagina to the ovaries is effected by the same kind of action as that which causes them to traverse the field of the microscope. We have seen, however, that not only spermatozoids, but sperm itself, have been found in the uterus and Fallopian tubes. Future observations may shed farther light on this obscure subject.

When treating of the views recently embraced by many physiologists as to the ovarian cause of menstruation, it was stated, that conception has been believed to be more easy during menstruation, or immediately before, or immediately after. Some, indeed, as M. Pouchet,[5] have asserted, in the absence of adequate numerical evidence, the dangerous doctrine, that the aptitude scarcely exists at the middle of the interval between two menstrual periods, although there are numerous facts to show, that fecundation occurs in intermenstrual periods.[6] M. Coste[7] affirms, that the Morgue of Paris has, for years, yielded him many opportunities for establishing this. The generality of those physiologists believe, that it is not necessary for the fecundating material of the male to come in contact with the ovum in the ovary—although in the vegetable, which is often taken as the analogue, such contact is known to be indispensable. They believe, that after an ovum has escaped, it may meet and be acted upon by the male sperm, either in the Fallopian tubes or in the uterus; and some think, notwithstanding the facts already mentioned of ovarian pregnancy, and of spermatozoids having been found in the ovary, that neither the sperm nor any part of it can reach the ovary, and therefore impregnation can never be effected in it. A recent writer[8] considers it most probable, that in the human female, as well as in the females of animals, the desire for

[1] Elements of Physiology, translated by Baly, p. 1491, Lond., 1842.

[2] Art. Cilia, Cyclop. of Anat. and Physiology, part vii. p. 633, July, 1836.

[3] Elements of Physiology, translated by R. Willis, part i. p. 72, Lond., 1841.

[4] Principles of Human Physiology, Amer. edit., p. 758, Philad., 1855, and Elements of Physiology, Amer. edit., p. 456, Philad., 1846.

[5] Théorie Positive de la Fécondation des Mammifères, Paris, 1842; Bulletin de l'Académie, Jan., 1845, p. 64; and especially his Théorie Positive de l'Ovulation Spontanée, &c., 9ème Loi, p. 170, Paris, 1847.

[6] Ritchie, op. cit.

[7] Op. cit., p. 203.

[8] Girdwood, in London Lancet, Dec. 7 and 14, 1844.

sexual intercourse is greatest at the menstrual period "or heat," especially towards the decline of the discharge; at which latter period, he says, from observation on animals, it is proved that ova are usually discharged. Bitches, he says, are generally observed to be languid, and to refuse the male during the first few days of heat; but after this they become lively, and readily admit of being lined; and analogous to this is the indisposition of the human female during the early part of each menstrual period, previous to the discharge becoming fully established. It could be understood, that a fecundating copulation might occur in the last days of menstruation, and perhaps soon after its cessation, through the male sperm coming in contact with an ovum separated from the ovary, and in the Fallopian tubes, or uterus;—for we are told authoritatively, by M. Pouchet,[1] it is a "law," that, in the mammalia, fecundation never occurs unless the emission of ova coincides with the presence of seminal fluid, although the menstrual secretion itself—it might be presumed—would tend rather to throw out of the body the fecundating material; but if, as elsewhere said, and generally believed, fecundation *often* occurs a short time before menstruation, then the ovum could not have left the ovary,—if the facts above cited be correct,—and impregnation must have been effected in it. In the existing state of knowledge, then, this organ appears to be the seat of fecundation,—although the author is not disposed to assert, that it *cannot* be accomplished at the time of, or soon after, the escape of the ovum from the ovarium. If the views of M. Coste, however, are correct, the contact of the sperm must take place early after the escape of the ovum, inasmuch as he found on opening birds and mammiferous animals—which were kept separate from the males—that the ova, ten or twelve hours after their spontaneous separation from the ovaries, presented evident signs of decomposition; whence he infers, that fecundation can only be effected in the ovary, in the pavilion of the tube, and perhaps, also, in its upper third, and he regards the facts observed by him to be fatal to the views of those who consider fecundation practicable in other portions of the tube, and in the uterus.[2]

By many modern writers on the ovular theory of menstruation, it is maintained that a period of about eight days is needed for the passage of the unimpregnated ovum from the ovarium to the uterus, and its discharge from the female; M. Pouchet,[3] however,—according to whose "tenth fundamental law," in the human species and the mammalia, the ovum and the sperm meet normally in the uterus, or in the portion of the Fallopian tubes near it, and there fecundation is accomplished,—extends the time much beyond this. His view is, that in the human species, a vesicle of De Graaf is torn normally at each menstruation, which spontaneously discharges its contained ovule, either immediately afterwards, or within the first four days following. A period of from two to six days is generally required for it to clear the tube, and it is subsequently retained in the uterus for from two to six days by the decidua. "If"—he adds—"during the time of its translation and so-

[1] Théorie Positive de l'Ovulation, &c., p. 209.
[2] Comptes Rendus, xxx. 691, Paris, 1850.
[3] Op. cit., pp. 297 and 467.

journ in the genital apparatus—that is, during the first twelve days that follow menstruation, and rarely up to the fourteenth day—there is sexual intercourse, fecundation may take place; but it can never be effected at a later period, because the ovum must manifestly have been dragged out by the decidua."

It is an overwhelming objection, however, to these views, that the Jewish women are bound to observe abstinence from sexual intercourse for eight days; and it is affirmed by Dr. Girdwood,[1] that "it is the custom amongst Jews, who are scrupulous, for the wife to retire from the society of her husband for a period of *thirteen* days, reckoning from the first day of being 'nyddar;'—that is to say, by those who are strict, five days are kept, as prescribed by the Rabbinical law (for the purpose of making security doubly sure) in addition to the eight days enforced by the law of Moses,"[2] and he adds "as a fact, that in general, among this singular people, no female is found to be a mother before at least nine calendar months and a half have elapsed,"—whence, he infers, that fecundation must have taken place immediately *before* the catamenial period. How fatal are such facts, observed on a large scale, to the dangerous doctrine of M. Pouchet and others, that intercourse cannot prove fecundating after twelve or fourteen days from the separation of the ovule from the ovary, especially when it is borne in mind, that the Jewish women are celebrated for being prolific. One single well observed antagonistic case would, indeed, be sufficient to disprove it, and such a one, recorded by Dr. Montgomery, of Dublin, is referred to hereafter, under the head of Duration of Pregnancy. In that case, the last menstruation occurred on the 18th of October; and the fecundating intercourse took place on the 10th of November, or twenty-three days afterwards. The case referred to by Dr. Dewees under the same head is equally opposed to the presumption. A similar case is given by Hirsch;[3] and Dr. James Reid[4] has collected several cases to determine the duration of pregnancy in the human female, which establish the same point. Moreover, from the data afforded by MM. Pouchet and Raciborski, M. Coste infers, that "there is not in the entire month a single moment in which the emission of ova and impregnation are impossible."[5]

Granting that conception occurs in the ovarium, and that sperm is projected into the uterus, with or without the actions referred to; in what manner does the sperm exert its fecundating agency on the ovarium? It is manifestly impossible, that the force of projection from the male can propel it not only as far as the cornua of the uterus, but also through the narrow media of communication between the uterus and ovary by the Fallopian tubes. This difficulty suggested the idea of the *aura seminis* or *aura seminalis*, which, it was supposed, might readily pass into the uterus, and through the tubes to the ovary. Dr.

[1] Appendix to W. Tyler Smith, Parturition and the Principles and Practice of Obstetrics, Amer. edit., p. 386, Philad., 1849.

[2] See, on this point, Hirsch, Jr., Einige praktische Bedenken gegen die jezt herrschende Zeugungstheorie, in Henle und Pfeuffer's Zeitschrift, neue Folge, 1852, Bd. ii. S. 127; and in Canstatt's Jahresbericht, 1852, S. 209.

[3] Op. cit.

[4] Lancet, July 20, 1850; and Amer. Journ. of the Med. Sciences, Oct., 1850, p. 522.

[5] Histoire Générale et Particulière du Développement, &c., p. 199, Paris, 1847.

Haighton, indeed, embraced an opinion more obscure than this, believing, that the semen penetrates no farther than the uterus, whence it acts on the ovaria by sympathy;—and this obscure view has been adopted by some distinguished individuals.

In opposition to the notion of the *aura seminis*, we have some striking facts and experiments. In all those animals, in which fecundation is accomplished out of the body, direct contact of the sperm appears necessary. Spallanzani and MM. Prévost and Dumas found, in their experiments on artificial fecundation, that they were always unsuccessful when they simply subjected ova to the emanation from sperm. Spallanzani took two watch-glasses capable of being fitted to each other, the concave surface of the one being opposed to that of the other. Into the lower he put ten or twelve grains of sperm, and into the upper about twenty ova. In the course of a few hours the sperm had evaporated, so that the ova were moistened by it; yet they were not fecundated; but fecundation was readily accomplished by touching them with the sperm that remained in the lower glass. A similar experiment was performed by MM. Prévost and Dumas. They prepared about an ounce and a half of a fecundating fluid from the expressed humour of twelve testicles, and as many vesiculæ seminales. With two and a half drachms of this fluid they fecundated more than two hundred ova. The remainder of the fluid was put into a small retort, to which an adopter was attached. In this, forty ova were placed, ten of which occupied the hollowest part, whilst the rest were placed near the beak of the retort. The apparatus was put under the receiver of an air-pump, and air sufficient was withdrawn to diminish the pressure of the atmosphere one-half. The rays of the sun were now directed upon the body of the retort, until the temperature within rose to about 90°; and after the lapse of four hours, the experiment was stopped; and the following were the results. The eggs at the bottom of the adopter were bathed with a transparent fluid, the product of distillation. They had become tumid, as in pure water, but had undergone no developement. The eggs near the beak of the retort were similarly circumstanced, but all were readily fecundated by the thick sperm that remained at the bottom of the retort. No aura nor emanation from the sperm, consequently, appeared to be capable of impregnating the ova. Absolute contact was indispensable. This is probably the case with the human female, and if so, the sperm must proceed from the uterus along the Fallopian tube to the ovarium. The common opinion is, that during the intense excitement at the time of copulation, the tube is raised, and its digitated extremity applied to the ovary. The sperm then proceeds along it,—in what manner impelled we know not,—and attains the ovary. According to Dr. Blundell and others, during the time of intercourse, the whole of the tube is in a state of spontaneous movement. Mr. Cruikshank pithed a female rabbit when in heat, and examined the uterine system minutely. The external and internal parts of generation were found black with blood; the Fallopian tubes were twisted like writhing worms, and exhibited a very vivid peristaltic motion; and the fimbriæ embraced the ovaries—like fingers laying hold of an object—so closely and firmly as to require force, and even slight laceration to disengage them. Haller states, that by injecting the vessels

of the tube in the dead body, it assumed this kind of action. De Graaf, too, affirms, that he has found the fimbriated extremity adhering to the ovary, twenty-seven hours after copulation; and M. Magendie has seen the extremity of the tube applied to a vesicle.

As excitement of some form would appear to be necessary to cause the digitated extremity of the tube to embrace the ovary, it would seem probable, that a female could not be impregnated without some consciousness of sexual union. This may be imperfect, as during sleep, or when in a state of stupor—either from spirituous liquors or narcotics—but still some impression must be made in order that fecundation may take place. It would not seem to be necessary, however, that the excitement should be venereal, or appreciated by the brain, inasmuch as when infecund ova pass from the ovaries into the tubes, as during menstruation, the same application of the fringed extremities of the tubes to the ovary probably takes place. This may be owing to a reflex or excito-motory action commencing in the uterus or ovary.

As the aura seminis appears to be insufficient for impregnation, it is obviously a matter of moment, that the sperm should be projected as high up the vagina as possible. It has been often observed, that where the orifice of the urethra does not open at the extremity of the glans, but beneath the penis, or at some distance from the point, the individual has been rendered less capable of procreation. In two cases, that fell under the care of the author, the urethra was opened opposite the corona glandis by a sloughing syphilitic sore; and the aperture continued, in spite of every effort to the contrary. The individuals were married, and the fathers of three or four children; but after this occurrence they had no increase of their families. Many medico-legal writers have considered, that when the urethra terminates at another than its natural situation, impotence is the necessary result,—and that although copulation may be effected, impregnation is impracticable. Zacchias,[1] however, gives a case to the contrary. M. Belloc,[2] too, asserts, that he knew of a person, in whom the orifice of the urethra terminated at the root of the frænum, who had four children that resembled the father, two having the same malformation; and Dr. Francis refers to the case of an inhabitant of New York, who, under similar circumstances, had two children. Many such cases, are, indeed, on record.[3] We cannot, therefore, regard it as an absolute cause of impotence; but the inference is just, that if the semen be not projected far up the vagina, and in the direction of the os uteri, impregnation is not likely to be accomplished; a fact, which it might be of moment to bear in mind, where the rapid succession of children is an evil of magnitude. Yet, notwithstanding this weight of evidence, it has been affirmed by Professor Heim,[4] that impregnation may take place by the simple contact of sperm with the lower part of the abdomen. The answer to this view, by M. D'Outrepont,[5] appears, however,

[1] Quæstiones Medico-Legales, Lugd., 1674.
[2] Cours de Médecine Légale, p. 50, Paris, 1819.
[3] Beck's Elements of Medical Jurisprudence, 6th edit., p. 71, Philad., 1838.
[4] Wochenschrift für die Gesammte Heilkunde; and Gazette Médicale, Sept. 25, 1836.
[5] Neue Zeitschrift für Geburtskunde, von Busch, d'Outrepont und Ritgen, B. iv. H. ii., Berlin, 1836; cited in Amer. Med. Intelligencer, p. 275, Nov. 1, 1837.

overwhelming. Heim relies on statements made by the parties that no penetration existed; but M. D'Outrepont properly observes, that whenever this has been alleged in a case of pregnancy, he has found, if the parties were strictly questioned, that one or both of them admitted, that the male organ *might* have been in the vagina, or at least in the vulva.

The part, then, to which sperm is applied is the ovary,[1] and by some it has been believed, that the liquor seminis is the substance that passes through the parietes of the follicle by imbibition, in order to reach the ovum. Mr. T. W. Jones[2] states, that although he is not prepared to deny this; yet, when he takes into consideration all the evidence on the subject, he is of opinion, that there is no proof, that fecundation takes place until the ovum has escaped from the Graafian follicle, and comes into direct contact with the sperm. Bischoff and Wagner[3] were, until recently, of opinion, that fecundation is accomplished by the liquor sanguinis; but the latter now considers the view to be less admissible than he did formerly; urging, amongst other reasons, that a liquor seminis is positively not traceable in many, especially of the lower, animals,—as worms, insects, &c.,—the whole mass of the sperm being formed by spermatozoids alone. He urges further against the idea of the liquor seminis being the agent in fecundation, that its action on the ova would be impossible in many cases,—for instance, where fecundation takes place in water without any real act of copulation,—the sperm being ejected, and left to chance as to whether it may come in contact with ova or not.[4] Bischoff, too, has abandoned his former opinion, and now maintains, that "spermatozoids and ova are constituents of an organism;" and that a positive contact of the two is necessary for the formation of a new being.[5]

It was before remarked, that Dr. Barry[6] had seen spermatozoids within the ova of the rabbit; and their entrance into the ova of animals has been confirmed by many observers; as by Dr. Neilson,[7] Mr. Newport,[8] Keber,[9] and others. Bischoff, who opposed the view, now admits their passage into the ova of the frog and the rabbit. Meissner found them often within the ova of the former animal; and he describes the ova of several insects with their micropyles, through which the spermatozoids enter;—and similar observations have been made by Leuckart.[10]

[1] Brachet, Physiologie Élémentaire de l'Homme, 2de édit., ii. 315. Paris et Lyon, 1855.

[2] Report on the Ovum of Man and the Mammifera, in Brit. and For. Med. Rev., Oct., 1843, p. 525.

[3] Elements of Physiology, by R. Willis, p. 74, Lond., 1844.

[4] Art. Semen, Cyclopædia of Anat. and Physiology, Pt. xxxiv. p. 507, Lond., Jan., 1849.

[5] Müller's Archiv. für Anatom., No. v. p. 441, Berlin, 1847.

[6] See, also, Monthly Journ. of Med. Science, Jan., 1855, p. 33, and Apr., 1855, p. 313.

[7] Philosophical Transactions, 1852.

[8] Philosophical Transactions, 1853, pp. 266–281; Carpenter, Principles of Human Physiology, Amer. edit., p. 764, Philad., 1855.

[9] Ueber den Eintritt der Samenzellen in das Ei, Königsberg, 1853, or De Spermatozoorum Introitu in Ovula, Autore G. A. F. Keber, p. 18, Königsberg, 1853, and Wagner, Nachtrag zum Nachtrag des Artikels Zeugung, in Wagner's Handwörterbuch der Physiologie, iv. 1017, Braunschweig, 1853.

[10] Hermann Weber, Annals of Physiology, in Brit. and For. Med.-Chir. Rev., Jan., 1856, p. 237.

Let us now inquire into the changes experienced by this body after a fecundating copulation. Fabricius, of Acquapendente,[1] having killed hens a short time after they had been trodden, examined their ovaries, and observed,—amongst the small yellow, round granules, arranged racemiferously, which constitute those organs,—one having a small spot, in which vessels had become developed. This increased in size, and was afterwards detached, and received by the oviduct; becoming covered, in its passage through that tortuous canal and the cloaca by particular layers, especially by the calcareous envelope; and being ultimately extruded in the form of an egg. Harvey,[2] in his experiments on the doe, made similar observations. He affirms, positively, that the ovary furnishes an ovum, and that the only difference, which exists amongst animals in this respect, is, that in some the ovum is hatched after having been laid; whilst in others it is deposited in a reservoir—a womb—where it undergoes successive changes. De Graaf[3] instituted several experiments on rabbits for the purpose of detecting the series of changes in the organs from conception till delivery. Half an hour after copulation, no alteration was perceptible, except that the cornua of the uterus appeared a little redder than usual. In six hours, the coverings of the ovarian vesicles seemed reddish. At the expiration of a day from conception, three vesicles in one of the ovaries, and five in the other, appeared changed, having become opaque and reddish. After twenty-seven, forty, and fifty hours, the cornua of the uterus and the tubes were very red, and one of the tubes had laid hold of the ovary; a vesicle was in the tube, and two in the right cornu of the uterus. These vesicles were as large as mustard seed. They were formed of two membranes, and were filled by a limpid fluid. On the fourth day, the ovary contained only a species of envelope, called, by De Graaf, a *follicle;* this appeared to be the capsule that had contained the ovum. The ovum itself was in the cavity of the uterus; had augmented in size, and its two envelopes were very distinct. Here it remained loose until the seventh day, when it formed an adhesion to the uterus. On the ninth day, De Graaf observed a small opaque point, a kind of cloud, in the transparent fluid that filled the ovum. On the tenth day, this point had the shape of a small worm. On the eleventh, the embryo was clearly perceptible; and from this period, it underwent its full developement, until the thirty-first day, when delivery took place. Malpighi[4] and Vallisnieri[5] also observed, in their experiments, that after a fecundating copulation, a body was developed at the surface of the ovary, which subsequently burst, and suffered a smaller body to escape. This was laid hold of by the tube, and conveyed to the uterus. It is not, however, universally admitted, that this body is the impregnated ovum; some affirming, that it is a sperm similar to that of the male; and others, that it is an amorphous substance, which, after successive developements, becomes the new individual.[6]

[1] Opera., Lips.
[2] De Generatione, p. 228.
[3] Tom. i. 310.
[4] De Formatione Pulli in Ovo, Lond., 1673; and De Ovo Incubato, Lond., 1686.
[5] Istoria della Generazione dell'Uomo, Discorsi Academ. iv., Venez., 1722–1726.
[6] Adelon, Physiologie de l'Homme, iv. 74.

Haller exposed the females of sheep and other animals to males on the same day, and killed them at different periods after copulation, for the purpose of detecting the whole series of changes by which the vesicle is detached from the ovary and conveyed to the uterus. Half an hour after copulation, one of the vesicles of the ovary appeared to be prominent; to have on its convexity a red, bloody spot, and to be about to break; in an hour or more, the vesicle gave way, and its interior seemed bleeding and inflamed. What remained of the vesicle in the ovary, and appeared to be its envelope, gradually became inspissated, and converted into a body of a yellowish color, to which he gave the name *corpus luteum.* The cleft, by which the vesicle escaped, was observable for some time; but, about the eighth day, it disappeared. On the twelfth day, the corpus luteum became pale, and began to diminish in size. This it continued to do until the end of gestation; and ultimately became a small, hard, yellowish or blackish substance, which could always be distinguished in the ovarium by the cicatrix left by it. Its size was greater, the nearer the examination was made to the period of conception. In a bitch, for example, on the tenth day, it was half the size of the ovary; yet it proceeded, in that case, from one vesicle only. In multiparous animals, as many *corpora lutea* existed as fœtuses.

The experiments of Haller[1] have been frequently repeated with similar results. M. Magendie,[2] whose trials were made on bitches, observed, that the largest vesicles of the ovary were greatly augmented in size, thirty hours after copulation; and that the tissue of the ovary surrounding them had acquired greater consistence; changed colour, and became of a yellowish-gray. This part was the *corpus luteum.* It, as well as the vesicles, increased for the next three or four days; and seemed to contain, in its areolæ, a white, opaque fluid, similar to milk. The vesicles now successfully ruptured the external coat of the ovary, and passed to the surface of the organ, still adhering to it, however, by one side. Their size was sometimes that of a common hazelnut; but no germ was perceptible in them. The surface was smooth, and the interior filled with fluid. Whilst they were passing to the uterus, the corpus luteum in the ovary underwent the changes referred to by Haller.

In similar experiments, instituted by MM. Prévost and Dumas,[3] no change was perceptible in the ovary during the first day after fecundation; but, on the second, several vesicles enlarged, and continued to do so for the next four or five days, so that from being two or three millimètres in diameter, they were eight. From the sixth to the eighth day, the vesicles burst, and allowed an ovule to emerge, which often escaped observation, owing to its not being more than half a millimètre in diameter; but was clearly seen by MM. Prévost and Dumas by the aid of the microscope. This part they termed *ovule,* in contradistinction to that developed in the ovary, which they called *vesicle.* The latter had the appearance, on its surface, of a bloody cleft, into which a probe might be passed; and in this way it could be shown, that the

[1] Element. Physiologiæ, lib. xxix. sect. 1, Bern., 1766.
[2] Précis de Physiologie, edit. citat., ii. 534.
[3] Annales des Sciences Naturelles, iii. 135.

vesicle had an interior cavity, which was the void space left by the ovule after its escape from the ovarium into the Fallopian tube. On the eighth day, in the bitch, the ovule passed into the uterus. All the ovules did not, however, enter that cavity at the same time,—an interval of three or four days sometimes occurring between them. When they attained the cavity, they were at first free and floating; and if examined with a microscope magnifying twelve diameters, seemed to consist of a small vesicle, filled with an albuminous, transparent fluid. If examined in water, their upper surface had a mammiform appearance, with a white spot on the side. This was the *cicatricula.* These ovules speedily augmented in size, and, on the twelfth day, fœtuses could be recognised in them.

Similar experiments, with like results, were made by Von Baer,[1] Seiler,[2] and others; and much minute attention has been paid to the subject by recent histologists,—by Wagner, Barry, Bischoff, T. W. Jones, Pouchet and Coste, more especially. As regards the ovarian changes, Wagner affirms, that after a fecundating intercourse, an increased flow of blood takes place to the ovaries; the vascular membrane of the Graafian vesicle enlarges; the granules mingled with its contents become greatly developed, and changed; and thickening and general increase of its walls, particularly of the base and sides, supervene; the ovum and other contents of the follicle are by this pressed forwards, or against that aspect of the follicle, which is in contact with the peritoneum, and which now becomes thinner and thinner, and finally bursts, so that the ovum escapes, and a cavity is left in the ovary, which is soon obliterated by the growth on all sides of the inner membrane of the follicle; a reddish, fleshy-looking mass sprouts from the walls towards the shrinking cavity, and the rent by which the ovum had escaped is finally closed. The follicle, thus altered, constitutes the *corpus luteum.* This is the generally received opinion, and it is analogous to that long since entertained by Haller. The outer layer of the Graafian follicle is considered to be of a fibrous structure, and therefore more elastic than the internal, whose structure is cellulo-vascular. The former, therefore, contracts more; and the latter being intimately united with it follows its movement, and consequently becomes thrown into folds or wrinkles, which project into the cavity: at the same time, according to M. Coste,[3] it becomes hypertrophied, and a plastic secretion takes place into the cavity, which unites the folds together and is the blastema in the filling up of the follicle. The cicatrix left by the aperture in the follicle through which the ovum has escaped differs in form in different animals. In the human female it is an irregular and generally stelliform cleft.—But the corpus luteum will receive further attention presently.

From the above facts, then, we may conclude, that the effect of fecundation is to excite the vesicles in the ovaries to developement; that the ova, within the germinal part, burst their covering; are laid hold of by

[1] De Ovo Mammalium, &c., Epist., Lips., 1827.

[2] Das Ei und Die Gebärmutter des Menschen, Dresd., 1832.

[3] Histoire Générale et Particulière du Développement des Corps Organisés, p. 249, Paris, 1849; and Baly and Kirkes, Recent Advances in the Physiology of Motion, Senses, Generation and Developement, p. 52, Lond., 1848.

the Fallopian tube, and conveyed to the uterus, where they remain during the period of gestation.

In the passage of the ova along the Fallopian tube it has generally been believed, that they experience but little change. They carry off, according to Wagner, a small portion of the granular stratum of the vesicle with them, which appears hanging to them at first as an irregular, ragged, discoidal appendage; but this is soon detached. The ovum gains a little in size; but there is still no trace of any special spot where the embryo originates. It would seem, however, from the researches of British embryologists, that the outer membrane of the ovum, which it acquired in the ovary, becomes swollen with moisture in the tube, and assumes the appearance of a thick, gelatinous-looking membrane, formed probably by cells—the proper *chorion ;* and by and by, the zona pellucida having disappeared, the newly-formed chorion comes to be the only investment of the yolk. All the observations on the ovum in the Fallopian tubes have, however, been made on animals. Of the human ovum whilst in the tubes, little or nothing is known.

The exact time required by the ovum or ova to make their way into the uterus, has not been accurately determined. Mr. Cruikshank[1] found, that in rabbits forty-eight hours were necessary. Dr. Haighton[2] divided one of the Fallopian tubes in a rabbit; and, having exposed the animal to the male, he observed that gestation occurred only on the sound side. On making this section after copulation, he found, that if it were executed within the first two days, the descent of the ovules was prevented; but if it were delayed for sixty hours, the ovules had passed through the tube and were in the cavity of the uterus. A case is quoted by writers on this subject, on the authority of a surgeon named Bussières, who observed an ovoid sac, about the size of a hazelnut and containing an embryo, half in the Fallopian tube and half adherent to the ovary.[3] The minuteness of the calibre of the Fallopian tube is not as great a stumbling-block in the way of understanding how this passage is effected as might appear at first sight. The duct is, doubtless, extremely small in the ordinary state; but it admits of considerable dilatation. M. Magendie[4] asserts, that he once found it half an inch in diameter; and the size of the ovum, we have seen, is only about $\frac{1}{200}$th part of an inch.

The period that elapses between a fecundating copulation and the entrance of the ovum into the uterus is different in different animals. In sheep, according to Haller[5] and Kuhlemann,[6] it happens on the seventeenth day. In rabbits, it is uncertain, but occurs generally on the third or fourth day after copulation;[7] in bitches on the fifth, according to some, but not till after the lapse of ten or twelve days, according to others; and in the human female, perhaps about the same time; yet Mr. Burns infers from analogical evidence, that we should be more

[1] Philosoph. Transactions for 1797. [2] Ibid., lxxxvii. 304.
[3] Adelon, Physiologie de l'Homme, edit. cit., iv. 78.
[4] Précis, &c., edit. cit., p. 535.
[5] Element. Physiol., viii. 59.
[6] Observ. quædam circa Negotium Generationis in Ovibus fact., Gotting., 1753.
[7] Recherches sur la Génération des Mammifères par Coste, suivies de Recherches sur la Formation des Embryons, par Delpech et Coste, Paris, 1834.

justified in the belief, that the ovum, in the human female, does not enter the uterus until at least three weeks after conception.[1] M. Maygrier refers to a case of abortion twelve days after copulation; the abortment consisting of a vesicle, shaggy on its surface, and filled by a transparent fluid. A case that has by many been considered one of the most instructive that we possess on this subject is given by Sir Everard Home,[2] and although, as Dr. Granville[3] has remarked, it has lately been the fashion to doubt its accuracy, or to esteem it morbid, there is not sufficient reason, perhaps, to discard it, more especially as Mr. Bauer's microscopic examination of the ovule, and description of its structure correspond with the more recent discoveries of Professor Boer. A servant-maid, twenty-one years of age, had been courted by an officer, who had promised her marriage, in order that he might more easily accomplish his wishes. She was but little in the habit of leaving home, and had not done so for several days, when she requested a fellow-servant to remain in the house, as she was desirous of calling upon a friend, and should be detained some time. This was on the 7th of January, 1817. After an absence of several hours, she returned with a pair of new corsets, and other articles of dress which she had purchased. In the evening she got one of the maidservants to assist her in trying on the corsets. In the act of lacing them, she complained of considerable general indisposition, which disappeared on taking a little brandy. Next day, she was much indisposed. This was attributed to the catamenia not having made their appearance, although the period had arrived. On the following day, there was a wildness in her manner, and she appeared to suffer great mental distress. Fever supervened, which confined her to her bed. On the 13th, she had an epileptic fit followed by delirium, which continued till the 15th, when she expired in the forenoon. On making inquiries of her fellow-servants, many circumstances were mentioned, which rendered it highly probable, that on the morning of the 7th, when she was immediately on the point of menstruating, her lover had succeeded in gratifying his desires; and that she had become pregnant on that day; so that, when she died, she was in the 7th or eighth day of impregnation. Dissection showed the uterus to be much larger than in the virgin state; and considerably more vascular. On accurately observing the right ovarium, in company with Mr. Clift, Sir Everard noticed, upon the most prominent part of its outer surface, a small ragged orifice. This induced him to make a longitudinal incision in a line close to the orifice, when a canal was found leading to a cavity filled with coagulated blood, and surrounded by a narrow yellow margin, in the structure of which the lines had a zigzag appearance. The cavity of the uterus was then opened, by making an incision through the coats from each angle; and from the point where these incisions met, a third incision was continued down through the os uteri to the vagina. The os uteri was found completely blocked up by a plug of mucus, so that nothing could have escaped by the vagina; the orifices leading to the Fallopian tubes were

[1] The Principles of Midwifery, &c., 3d edit, p. 132, Lond., 1814.

[2] Philosophical Transactions for 1807, p. 252; and Lectures on Comparative Anatomy, iii. 288, Lond., 1823.

[3] Graphic Illustrations of Abortion, &c., p. 7, Lond., 1834.

both open, and the inner surface of the uterine cavity was composed of a beautiful efflorescence of coagulable lymph resembling the most delicate moss. By attentive examination, Sir Everard discovered a small, spherical, transparent body concealed in this efflorescence, which was the impregnated ovum. This was submitted to the microscopic investigations of Mr. Bauer, who made various drawings of it, and detected two projecting points, which were considered to mark out, even at this early period, and before the ovum was attached to the uterus, the seat of the brain and spinal marrow.

This case—if admitted as a correct observation—shows, that an ovum had left the ovary, and was in the interior of the uterus, prior to the seventh or eighth day after impregnation. Weber and Von Baer, however, have each recorded a case in which there was an opportunity for examining the embryo, probably eight days after a fecundating copulation; but no ovum was detected either in the uterus or tube, and it must be admitted, that some of the best observers—as will be stated hereafter—do not consider that the ovum enters the uterus before the 10th or 12th day after it quits the ovary. On comparing the degree of advancement of the fœtus in the human ovum, as described by different observers, with that of the fœtus in the dog, cat, and sheep, at known periods, Dr. Allen Thomson[1] hazards the opinion, that it does not arrive in the uterus before the eleventh or twelfth day after conception:—Valentin, indeed, thinks, the twelfth or fourteenth day. From this discrepancy amongst observers, it is manifest, that our knowledge on the matter is by no means definite.

But—it has been asked—is it a mere matter of chance which of the ovarian vesicles shall be fecundated; or are there not some riper than the rest, that receive, by preference, the vivifying influence of the sperm? MM. Prévost and Dumas have shown, that such is the case with oviparous animals. They found, in their experiments, that not only were the vesicles of the ovaries of frogs of different sizes, but that the largest were always laid first, whilst the smallest were not to be deposited until subsequent years. In all animals, whose eggs were fecundated externally, they seemed evidently prepared or maturated. We have, too, the most indubitable evidence that birds—although unquestionably virgins—may lay infecund eggs; and analogy would lead us to believe, that something similar may happen to the viviparous animal; a position which has been confirmed by direct observation.

In all cases in which an ovum has escaped, a cavity of course is left in the ovarium, which is filled up, in the manner already mentioned, by a growth from the Graafian follicle, which constitutes the *corpus luteum*.

Not longer ago than the year 1808, the existence of this body in the ovarium was held to be full proof of impregnation. In that year, Charles Angus, Esq., of Liverpool, England, was tried at the Lancaster Assizes, for the murder of Miss Burns, a resident of his house.[2] The symptoms previous to her decease, and the appearances observed on

[1] Art. Generation, in Cyclop. of Anat. and Physiol., part. xiii. p. 454, Feb., 1838.
[2] Edinb. Med. and Surg. Journal, v. 220.

dissection, were such as to warrant the suspicion that she had been poisoned. The uterine organs were also found to be in such a state as to induce the belief, that she had been delivered a short time before her death of a fœtus, which had nearly arrived at maturity. It was not, however, until after the trial, that the ovaria were examined in the presence of a number of physicians; when a *corpus luteum* was distinctly perceived in one of them. The uterus was taken to London, and shown to several of the most eminent practitioners; all of whom appear to have considered, that the presence of a *corpus luteum* proved the fact of pregnancy beyond a doubt. Such, indeed, is the positive averment of Haller,[1] an opinion which was embraced by Dr. Haighton,[2] who maintained, that they furnish "incontestable proof" of previous impregnation. It was this belief,—coupled with the fact, that division of the Fallopian tubes, in his experiments, prevented impregnation, whilst corpora lutea were found, notwithstanding, in the ovary,—which led him to the strange conclusion, that the semen penetrates no farther than the uterus, and acts upon the ovaria by sympathy.

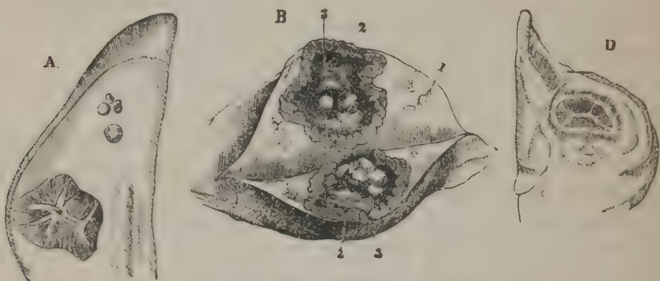
Sir Everard Home[3] affirmed, that corpora lutea exist independently of impregnation. "Upon examining," said he, "the ovaria of several women, who had died virgins, and in whom the hymen was too perfect to admit of the possibility of impregnation, there were not only distinct corpora lutea, but also small cavities around the edge of the ovarium, evidently left by ova, that had passed out at some former period;" and he affirms, that whenever a female quadruped is in heat, one or more ova pass from the ovaria to the uterus, whether she receives the male or not. This view of the subject appears to have been first propounded by Blumenbach,[4] who remarks that the state of the ovaria of females, who have died under strong sexual passion, has been found similar to that of rabbits during heat; and he affirms, that in the body of a young woman, eighteen years of age, who had been brought up in a convent, and had every appearance of being a virgin, Vallisnieri found five or six vesicles pushing forward in one ovarium, and the corresponding Fallopian tube redder and larger than usual, as he had frequently observed in animals during heat. Bonnet, he adds, gives the history of a young lady, who died vehemently in love with a man of low station, and whose ovaria were turgid with vesicles of great size; and similar facts have been recorded by numerous observers.[5] It has been already remarked, under Menstruation, that the periodical recurrence of that function has been supposed by some to consist in the production and developement of vesicles in the ovary; that is, of a matured ovum which is periodically brought forward either to be expelled with the menstrual flux, or to be destroyed in the genital organs.

Buffon, again, maintained, that instead of the corpus luteum of Haller being the remains of the ovule, it is its rudiment; and that the corpus exists prior to fecundation,—as he, also, found it in the virgin.

[1] Element. Physiolog., xxix. 1.
[2] Philosoph. Transact., lxxxvii. 159.
[3] Philosoph. Transact. for 1817 and 1819; and Lectures on Compar. Anat., iii. 304.
[4] Comment. Soc. Roy. Scient., Gotting., ix. 128; and Elliotson's edit. of Blumenbach's Physiology, 4th edit., p. 468, Lond., 1828.
[5] Pouchet, Théorie Positive de l'Ovulation Spontanée, &c., p. 127, Paris, 1847.

Lastly, Dr. Blundell[1] states, that he has in his possession a preparation, consisting of the ovaries of a young girl, who died of cholera under seventeen years of age, with the hymen, which nearly closed the entrance of the vagina, unbroken. In these ovaries the corpora lutea are no fewer than four; two of them being a little obscure, but easily perceptible by an experienced eye. The remaining two are very distinct, and differ from the corpus luteum of genuine impregnation merely by their more diminutive size and the less extensive vascularity of the contiguous parts of the ovary. "In every other respect," says Dr. Blundell, "in colour and form, and the cavity which they contain, their

Fig. 432.



Corpora Lutea of different periods.

B. Corpus luteum of about the sixth week after impregnation, showing its plicated form at that period. 1. Substance of the ovary. 2. Substance of the corpus luteum. 3. A grayish coagulum in its cavity; after Dr. Patterson. A. Corpus luteum, two days after delivery. D. In the twelfth week after delivery.

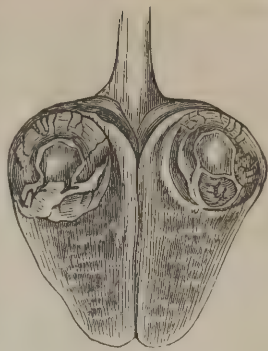
appearance is perfectly natural,—indeed, so much so, that I occasionally circulate them in the class-room, as accurate specimens of the luteum upon the small scale." Mr. Stanley[2] confirms the fact of the corpora lutea of virgins being of smaller size than those that are the consequences of impregnation; and Dr. Montgomery[3] says, he has seen many of these virgin corpora lutea, "as they are unhappily called," and has preserved several specimens of them; but not in any instance did they present what he would regard as even an approach to the assemblage of characters belonging to a true corpus luteum,—the result of impregnation; from which, according to him, they differ in the following particulars:—1. There is no prominence or enlargement of the ovary over them. 2. The external cicatrix is almost always wanting. 3. There are often several of them found in both ovaries, especially in subjects who have died of tubercular diseases, such as phthisis, in which case they appear to be

Fig. 433.

Corpus Luteum in the Third Month.

[1] Researches, Physiol. and Pathological, p. 49, Lond., 1825.
[2] Transactions of the Royal College of Physicians of London, vol. vi.
[3] An Exposition of the Signs and Symptoms of Pregnancy, &c., p. 245, Lond., 1837, or Amer. Med. Lib. edit., Philad., 1839; or art. Signs of Pregnancy and Delivery, in Cyclop. of Pract. Medicine, Amer. edit. by the author, Philad., 1844.

Fig. 434.



Corpus Luteum at the end of the Ninth Month.

merely depositions of tubercle, and are frequently without any discoverable connexion with the Graafian vesicles. 4. They present no trace whatever of vessels in their substance, of which they are, in fact, entirely destitute, and of course cannot be injected. 5. Their texture is sometimes so infirm, that it seems to be merely the remains of a coagulum, and at others appears fibro-cellular like that of the internal structure of the ovary; but never presents the soft, rich, lobulated, and regularly glandular appearance, which Hunter meant to express, when he described them as "tender and friable like glandular flesh." 6. In form they are often triangular, or square, or of some figure bounded by straight lines; and 7. They never present either the central cavity or the radiated or stelliform white line, which results from its closure. Figures 433 and 434, from Dr. Montgomery, represent the corpus luteum in the third, and at the end of the ninth month respectively.

Dr. William Davidson,[1] of Edinburgh, however, has published three dissections of females—not one of whom was pregnant—and in each, corpora lutea were found. They all possessed the characters assigned them by Dr. Montgomery, a central cavity, or fibrous coagulum; an oval form, and a radiated white cicatrix in the centre, just about the central body, which was *immediately* under the peritoneal coat. This last point is dwelt upon by Dr. Robert Lee, who maintains, that false corpora lutea are never observed in immediate connexion with the peritoneum,—a small portion of stroma intervening. One of the females had been in a weakly condition for some years, and had no children; another was unmarried, and had menstruated three days previous to her death; of the third, there was no history, but all the organs were healthy, and the Fallopian tubes and uterus in every respect natural. Dr. Davidson expresses his confident opinion, that in none of the cases had there been impregnation prior to the appearance of these bodies; and he refers to Professors Alison, Allen Thomson, John Reid, and Goodsir, in proof of the accuracy of his statement, and of their perfect resemblance to true corpora lutea. He states, as the result of his investigations, the belief, that impregnation cannot take place without the appearance of a true corpus luteum, but that a true corpus luteum may appear independently of impregnation. That the latter is the case in animals has been shown by the recent researches of Bischoff[2] and others.

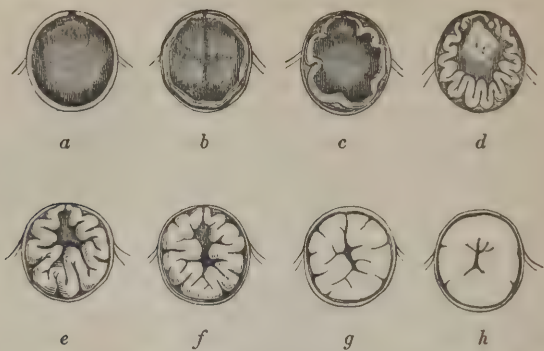
It is not yet decided at what period the central cavity disappears or closes up to form the stellated line. Dr. Montgomery thinks he has invariably found it existing up to the end of the fourth month. He has one specimen in which it was closed in the fifth, and another

[1] Lond. and Edinb. Monthly Journal of Med. Science, Dec., 1841.

[2] Beweis der von Begattung unabhängigen periodischen Reifung und Loslösung der Eier, Giessen, 1844; translated in Lond. Med. Gaz., Jan. 13, 17, &c., 1845.

in which it was open in the sixth; but later than this he has never found it.

Fig. 435.



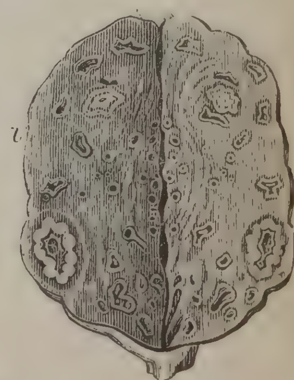
Successive Stages of the Formation of the Corpus Luteum, in the Graafian follicle of the Sow, as seen in Vertical Section.

At *a* is shown the state of the follicle immediately after the expulsion of the ovum, its cavity being filled with blood, and no ostensible increase of its epithelial lining having yet taken place; at *b*, a thickening of this lining has become apparent; at *c*, it begins to present folds which are deepened at *d*, and the clot of blood is absorbed *pari passu*, and at the same time decolorized; a continuance of the same process as shown at *e*, *f*, *g*, *h*, forms the Corpus Luteum, with its stellate cicatrix.

The structure of the corpus luteum is of a peculiar kind, and is not distinctly seen in small animals, or in those that have numerous litters; but in the cow, which commonly has only one calf at a birth, it is so large, according to Sir Everard Home,[1] that, when magnified, the structure can be made out. It is a mass of thin convolutions, bearing a greater resemblance to those of the brain than to any other

Fig. 436.

Fig. 437.



Corpora Lutea.

organ. Its shape is irregularly oval, with a central cavity, and in some animals, its substance is of a bright orange colour, when first exposed. The corpora lutea are found to make their appearance im-

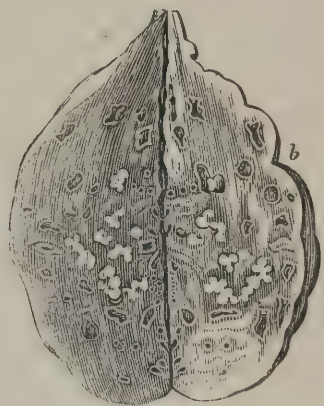
[1] Lect. on Comp. Anat., iii. 303.

mediately after puberty, and they continue to succeed each other, as the ova are expelled, till the period arrives when impregnation can no longer be accomplished. Sir Everard's theory, regarding these bodies, is, that they are glands, formed purposely for the production of ova,—and a similar view is entertained by Seiler;[1] that they exist previous to, and are unconnected with sexual intercourse; and, when they have fulfilled their office of forming ova, they are removed by absorption, whether the ova be fecundated or not.

Figures 436 and 437 afford an external and internal view of a human ovary, that did not contain the ovum, from which a child had been developed. It was taken immediately after the child was born.

Fig. 438.

Fig. 439.



Corpora Lutea.

The corpus luteum is nearly of the full size. Figs. 438 and 439 afford an external and internal view of the ovary, from which the impregnated ovum had escaped. Figure *b* exhibits how much the corpus luteum had been broken down. In it is seen a new corpus luteum forming.

From all these facts, it was at one time concluded by Sir Everard Home,[2] Messrs. Blundell, Saumarez,[3] Cuvier, and others,[4] that something resembling a corpus luteum may be produced independently of sexual intercourse, by the mere excitement of high carnal desire, and perhaps without it, during which the digitated extremity of the Fallopian tube embraces the ovary, a vesicle bursts its covering, and a yellow body remains. The ovule conveyed along the tube into the uterus being infecund, undergoes no farther developement; so that unimpregnated ova may,—it was inferred,—under such circumstances,

[1] Das Ei und die Gebärmutter des Menschen, u. s. w., Dresd., 1832.
[2] Op. cit., iii. 304.
[3] A New System of Physiology, i. 337.
[4] For a history of the opinions entertained at various times regarding the corpus luteum, see Dr. Paterson, Edinb. Med. and Surg. Journal, April, 1841, p. 402.

be discharged, as we observe in the oviparous animal. That infecund ova are thus discharged by the mammalia is now universally admitted. It has been generally denied, however, of late, that the intervention of the male has any influence whatever over it; but the observations of M. Coste[1] demonstrate, that this opinion is too exclusive. He found in rabbits killed from ten to fifteen hours after intercourse, that the ova had generally quitted the ovaries; whilst they were as generally retained where the female was carefully kept from the male.

When pregnancy is over, the corpus luteum gradually diminishes in size, and disappears. Dr. Montgomery was unable to fix the exact period of its total disappearance; but he has found it distinctly visible so late as the end of five months after delivery at the full time, but not beyond this period. It would seem, therefore, that a few months after the termination of pregnancy, all traces of the corpus luteum are lost; and that, consequently, it must be impracticable to decide how frequently impregnation has taken place, by examining the ovaries.

Such have been the sentiments of physiologists in regard to the formation of corpora lutea;—a marked difference being admitted by most of them to exist between those that result from the escape of infecund ova, and those that are the consequence of the escape of the impregnated: whilst others have regarded them as identical. With those, however, who maintain that ova always leave the ovary prior to fecundation, it would seem to be consistent to presume, that the corpora lutea are alike in all cases; and hence, that the ovaries can furnish no probable solution after death, by the appearance presented by the corpora lutea, of the question, whether the female had been impregnated or not. M. Raciborski at one time maintained this doctrine, affirming, that not merely as a result of conception, but at each menstrual period, the discharge of an ovum is followed by the formation of a corpus luteum. Since then, however, he appears to have changed his sentiments as regards the human female, but maintains that such is the fact in animals,—after each period of heat a corpus luteum being formed, which is undistinguishable from that formed after fecundation. The conclusions to which he now arrives are the following. *First.* Corpora lutea are produced by hypertrophy of the granular substance which lines the internal membrane of the Graafian vesicle. *Secondly.* The transformation of this substance commences as soon as the ovule attains maturity, and the vesicle is then prepared to break and give passage to it. *Thirdly.* As soon as the Graafian follicles burst, the transformation is rapidly developed. But an important distinction occurs. If the ovum has been expelled spontaneously—as at every menstrual period—the granulations increase in number and size, under the form of a thin, yellowish membrane, adherent to the membrane of the vesicle; and, in the cavity which it forms a small clot of blood is to be found. If, on the contrary, conception coincides with the expulsion, the elements of the granular tunic increase so much in size and number, that in a little time they form a voluminous

[1] Histoire Générale et Particulière du Développement des Corps Organisés, p. 183, Paris, 1847.

mass, which fills the whole cavity of the vesicle. In the centre of this yellow mass, a small whitish fibrinous tissue—the cicatrix indicating a former cavity—is with difficulty distinguishable. *Fourthly.* In all females delivered at the full period, corpora lutea of this description exist; but they rapidly waste and disappear after delivery. *Fifthly.* It results from the above, that by simple inspection cases of simple spontaneous expulsion of ova may be readily distinguished from those that have been followed by impregnation.[1]

They, who consider that fecundation is not accomplished in the ovary, must believe, that the ovarian changes, which accompany and signalize fecundation are produced by some reflex action from the uterus; and such is the view embraced by Dr. Ritchie, who has made elaborate inquiries on this whole subject. A similar view is maintained by M. Coste.[2] "When the fecundated ovum"—he remarks—"has attached itself to the uterus, it impresses on that organ an increase of activity, which lasts through the whole term of utero-gestation; extends its influence to the ruptured ovarian capsule, and gives a greater intensity to the process of cicatrization."

It has been a matter of discussion with histologists, whether the substance of the corpus luteum is deposited within the Graafian vesicle, externally to it, or between its layers, or whether it does not consist of a hypertrophied condition of the inner layer or ovisac. Von Baer, Valentin, Wagner, Bischoff, Raciborski, Zwicky, and others embrace the first and most probable opinion; and from an examination of many human corpora lutea in various stages of their growth, Dr. Baly[3] is satisfied, that this is the correct opinion; whilst MM. Pouchet and Coste embrace the last view; Dr. Robert Lee, Mr. T. Wharton Jones, the second; and Drs. Montgomery, Barry, Paterson, Ritchie, F. Renaud, and others, the third.

Dr. Ritchie[4] has shown, that a great variety of changes may take place in the ovary after the ovum has been discharged, amongst which may be included all the appearances depicted by those observers. Besides varying in seat, they differ considerably, he states, in aspect and character;—some being of a white colour, *corpora albida;* others brain-like,—*corpora cephaloidea;* and others, at first, similar to the last, but becoming subsequently of a decidedly red colour—*corpora rubra.* The *corpora albida* may exist under two forms;—first as *soft* bodies of a yellowish fatty appearance, having the outer coat much thickened, whilst the inner remains as a delicate diaphanous pellicle; these, after a long period, present themselves as yellowish-white, and generally globular bodies, more or less fissured from their contraction, and sometimes in process of absorption; having a granular-looking structure, and seldom divisible into laminæ by dissection; and secondly, as *dense* bodies of a whitish, shining, firm structure, the inner coat being the seat of those changes, and the outer adhering loosely as a

[1] Bulletin de l'Académie Royale de Médecine, Oct. and Nov., 1844; cited in Med. Examiner, June, 1845, p. 384.

[2] Op. cit., p. 259.

[3] Baly and Kirkes, Recent Advances in the Physiology of Motion, the Senses, Generation and Developement, p. 54, Lond., 1848.

[4] Op. cit.; also, Carpenter, Principles of Human Physiology, 2d Amer. edit., p. 597.

transparent pellicular layer. The inner layer has the appearance of a thick, opaque, deeply wrinkled cyst; or is at times partially diaphanous, and of a shining pearly aspect, and white colour; and sometimes contains a yellow, greenish, transparent fluid, or a clot of blood, either unchanged, or converted into a yellow or black pigment. Of the *corpora cephaloidea* Dr. Ritchie depicts many varieties, according as the cerebriform matter is deposited between the layers of ruptured follicles, having transparent pellicular walls, or having their inner or outer coat thickened; or externally to the two inner layers of the follicle. The last variety only was met with exclusively in the fecundated female. They were generally distinguished by large, persistent, white, glistening cavities. The granular cephaloid matter was sometimes found quite absorbed a few days after delivery; but, in other instances, it underwent changes characteristic of the next class.

The *corpora rubra* are peculiar to the impregnated and suckling female—in the period between the eighth and thirteenth months after conception. They appeared to Dr. Ritchie to be a conversion of the corpora cephaloidea, arising out of a higher and more perfect organization. Down to the seventh month of utero-gestation, the cysts contained in the ovaries do not differ from the cephaloid bodies found in the unimpregnated state, except that they are sometimes plumper; more vascular; better developed, and have their inner layer more frequently thickened. A change of the granular hue then commences, which becomes more and more decided; so that by the end of the first month after delivery, it is of a decided rose colour, changing to a still more florid hue on exposure to air. Its cavity also contracts, so as to leave only a stellated point, or a curved groove, with a fibrous appearance in the surrounding substance.

Although corpora rubra are found exclusively in the latter months of pregnancy, or in the puerperal state, yet, they are not always present in those conditions. The form of corpora cephaloidea described above, and the corpora rubra, according to Dr. Ritchie, alone coincide with pregnancy.

The cause of the yellow colour of the corpora lutea has been a ground of dispute; but it is obviously of no more moment than that of the other varieties of colour presented by those bodies. By MM. Pouchet,[1] Raciborski,[2] and others, it has been ascribed to extravasation and imbibition by the hypertrophied lining membrane, similar to that which occurs in ecchymosis, or in the neurine in cases of encephalic hemorrhage; but others[3] do not accord with this view. From the appearances presented under the microscope, Dr. Meigs argues, that the yolk of eggs and the yellow matter from a corpus luteum "are of the same apparent constitution, form, colour, odour, coagulability, refractive power, and microscopic appearance;" and M. Coste appears to be of the same opinion. Dr. Meigs,[4] for these reasons, considers it a true "*vitellary*

[1] Théorie Positive de l'Ovulation Spontanée, p. 146, Paris, 1847.

[2] De la Puberté et de l'Age Critique chez la Femme, p. 437, Paris, 1844.

[3] Coste, Op. cit., and Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 497, Philad., 1853.

[4] Transactions of the American Philosophical Society for 1847, p. 131; and Obstetrics: the Science and the Art, by Charles D. Meigs, M. D., p. 107, Philad., 1849.

matter." The propriety of such a name may be questioned, however, upon the same ground, that we might hesitate in calling a substance which contains cholesterin, *biliary matter;* as cholesterin is a constituent of many morbid formations totally unconnected with the liver, or its secretion. That the colouring matter of the vitellus or yolk and that of the corpus luteum are analogous—if not identical—is probable, under the view which we embrace,—that the corpus luteum is constituted essentially of the enlarged cells and granules of yellow fatty matter that line the Graafian vesicle and form the membrana granulosa. The enlargement of the cells, according to Zwicky,[1] who minutely examined the corpora lutea in cows and sows, appears to depend on an accumulation of the fat granules which the Graafian vesicles always contain; and the yellow colour, when it exists, is contained in those fat granules and other fatty particles. When it is borne in mind, that the vitellary matter of the ovum must be secreted from the same lining membrane of the Graafian vesicle as the membrana granulosa, there need be no difficulty in comprehending, that the yolk and the corpus luteum may be of identical or analogous composition, and conduct themselves alike under the microscope, and the employment of reagents. In function, however, they are in no respect identical or analogous.

It is obvious, that the value of the corpora lutea as an index of fecundation is in an unsettled condition; and, consequently, the medical jurist must be exceedingly cautious, from their appearance, in giving decided testimony in a court of justice; for although, as has been seen, some observers—Dr. Montgomery and Dr. Dalton,[2] for example—have pronounced strongly in regard to the markedly distinctive characters of the corpora lutea of impregnation; and M. Coste[3] expresses his belief in the possibility of distinguishing by them whether a female was or was not pregnant, and is persuaded that important applications will ultimately be made of this knowledge in legal medicine; others—as Dr. Davidson—have deposed as strongly to the absence of such characteristics; and all must admit, that in the present state of knowledge, the mere fact of the existence of a corpus luteum ought scarcely to be taken as a positive evidence of previous impregnation; yet, if it were larger than a common pea, it might be regarded as strong presumptive evidence in the affirmative.[4] M. Longet[5] affirms, that the corpora lutea of the unfecundated state rapidly run through their stages; never attain a high degree of developement; have a size not much less than the corpora lutea of impregnation; rapidly assume the yellow hue; become shrivelled in a few days; and, before a month or two, are retracted into, and completely confounded with the tissue of the ovary; whilst the corpora lutea of impregnation, participating in the congestion and activity of the physiological process in all the sexual organs, and especially in the uterus during gestation, attain a

[1] De Corporum Luteorum Origine atque Transformatione, cited by Mr. Paget in his Report on the Progress of Human Anatomy and Physiology, in the years 1844–5, in British and Foreign Medical Review, July, 1846, p. 290; also, Baly and Kirkes, op. cit., p. 53.

[2] Prize Essay on the Corpus Luteum of Menstruation and Pregnancy, in Transactions of the Amer. Med. Assoc., iv. 547, Philad., 1851.

[3] Op. cit., p. 260.

[4] Baly and Kirkes, op. cit., p. 57.

[5] Traité de Physiologie, ii. 88, Paris, 1850.

considerable size; and pass so slowly through the stages of formation and decrease, that they are still perceptible at the end of pregnancy. They gradually diminish in size as the fœtus becomes developed, and the term of gestation approaches. In an elaborate monograph, by Dr. Dalton,[1] he confirms the views of Longet, and considers that whilst the statements of the latter are altogether under the form of general deductions, no series of observations having been given by him to establish a conviction of their reliability, he alone—so far as he is aware—has absolutely demonstrated the difference between the two species of corpora lutea by recorded facts. The difficulty of accurate decision in every case, however, is shown by a controversy between two distinguished observers and writers on this matter,—Dr. R. Paterson, and Dr. Robert Lee. Dr. Paterson[2] had described what he conceived to be an early corpus luteum. This was designated by Dr. Lee, in his lectures, as a mere clot of blood; and he afterwards affirmed, that "the said clot of blood did not present one of the characters of a true corpus luteum;" and that if he "was summoned into a court of justice, he would have no hesitation in declaring upon oath, from the evidence furnished, that the proofs of pregnancy were wholly wanting." Dissatisfied with these remarks, Dr. Paterson forwarded, through a friend, the specimen in question, without stating what it was, to obtain Dr. Lee's unbiassed opinion of it from personal inspection; when, after a careful examination, Dr. Lee returned an answer, declaring it to be an early true corpus luteum, and requested permission to describe it as such before the Royal Medico-Chirurgical Society of London![3]

In regard to the offices performed by corpora lutea, difference of sentiment has existed, and still exists: Sir Everard Home—as has been seen—adopts the opinion of Vallisnieri, that they are glandular formations concerned in the production of ova. Others have supposed, that they furnish the ovum with the first materials that are needed for its developement.[4] The generality of physiologists, perhaps, regard them as the result of a simple process of cicatrization set up in the emptied vesicle,—a process, which, according to Bischoff,[5] bears the greatest analogy to that of the closure and healing of an abscess.

c. *Theories of Generation.*

We have now endeavoured to demonstrate the part performed by the two sexes in fecundation. It has been seen, that the material furnished by the male is sperm; that afforded by the female an ovum. The most difficult topic of inquiry yet remains,—how the new individual results from their commixture? Of the nature of this mysterious process we are profoundly ignorant; and if we could make any comparison between the extent of our ignorance of the different vital phenomena, we should be disposed to decide, that the function of generation is one of the least intelligible. The new being must be

[1] Op. cit., p. 642. [2] Edinb. Med. and Surg. Journ., No. 142.
[3] R. Paterson, in Edinb. Med. and Surg. Journ., Oct., 1844, p. 467.
[4] Montgomery, On the Signs and Symptoms of Pregnancy, &c., Amer. Med. Libr. edit., p. 149, Philad., 1839.
[5] Developpement de l'Homme, &c., traduit par Jourdan, p. 44, Paris, 1843.

stamped instantaneously as by a die. From the very moment of the admixture of the materials at a fecundating copulation, the embryo must have within it the powers necessary for its own formation,—impulses communicated by each parent, as regards likeness, hereditary predisposition, &c. From that moment the father has no communication with it; yet we know, that it may resemble him in its features and predispositions to certain morbid states,—whilst the mother probably exerts but a slight and indirect control over it afterwards; her office being chiefly to furnish the homunculus with a nidus, in which it may work its own formation, and with the necessary pabulum. We have seen, that even so early as the seventh and eighth day after fecundation, two projecting points—it has been asserted—have been observed in the ovum, which indicate the future situations of the brain and spinal marrow. [?] Our want of acquaintance with the precise character of this impenetrable mystery will not, however, excuse us from passing over some of the ingenious hypotheses, that have been entertained. These have varied according to the views that prevailed respecting the nature of the sperm; and to the opinions indulged regarding the matter furnished by the ovary. Drelincourt,[1] who died in 1697, collected as many as two hundred and sixty hypotheses of generation; but they may all, perhaps, be classed under two,—the system of *epigenesis* and that of *evolution.*

1. *Epigenesis.*—According to this system, which is the most ancient of all, the new being is conceived to be built of materials furnished by both sexes, the particles composing those materials having previously possessed the arrangement necessary for constituting it,—or having suddenly received such arrangement. Still, it is requisite that these particles should have some controlling force to regulate their affinity, different from the ordinary forces of matter; and hence one has been imagined to exist, which has been termed *cosmic*, *plastic*, *essential*, *nisus formativus*—Bildungstrieb, of the Germans—*force of formations*, &c.

Hippocrates[2] maintains, that each of the two sexes possesses two kinds of seed, formed by the superfluous nutriment, and by fluids constituted of materials proceeding from all parts of the body, and especially from the most essential,—the nervous. Of these two seeds, the stronger begets males, the weaker females. In the act of generation, these seeds are commingled in the uterus; and through the influence of the heat of that organ, they form the new individual—by a kind of animal crystallization—male or female, according to the predominance of the stronger or the weaker seed. Aristotle[3] thought, that it is not by seed that the female participates in generation, but by menstrual blood. This he conceived is the basis of the new individual, whilst the principles furnished by the male communicate to it the vital movement, and fashion it. Empedocles, Epicurus, and various other ancient physiologists, contended, that the male and female respectively contribute a seminal fluid, which co-operate equally in the generation and developement of the fœtus; and that it belongs to the male or female

[1] Novem Libelli de Utero, Conceptione, Fœtu, &c., Lugd. Bat., 1632.
[2] Περι γονης; in Oper. Omnia, edit. A. Foësio. Genev., 1657–1662.
[3] De Generatione Animalium, &c., i. 19.

sex, or resembles more closely the father or the mother, according as the orgasm of the one or the other predominates, or is accompanied by a more copious emission.

> "Semper enim partus duplici de semine constat;
> Atque utrique simile est magis id quodcumque creatur."
>
> LUCRET., lib. iv.

Lactantius, on quoting the views of Aristotle, fancifully affirms, that the right side of the uterus is the proper chamber for the male fœtus; the left for the female,—a belief, which appears to be still prevalent amongst the vulgar in many parts of Great Britain. But he adds; if the male or stronger semen should, by mischance, enter the left side of the uterus, a male child may still be conceived; yet, as it occupies the female department, its voice, face, &c., will be effeminate. On the contrary, if the weaker or female seed should flow into the right side of the uterus, and a female fœtus be engendered, it will exhibit evidences of a masculine character.

The idea of Aristotle with regard to the menstrual blood has met with few partisans, and is undeserving of farther notice. That of Hippocrates, notwithstanding the objections,—that the female furnishes no sperm, and the ovaria are in no respect analogous to the testes,—has had numerous supporters amongst the moderns, modified, however, to suit the scientific ideas of the time, and the individual. Des Cartes, for example, considered the new being to arise from a kind of fermentation of the seed furnished by both sexes. Pascal, that the sperm of the male is acid; that of the female alkaline; and that they combine to form the embryo. Maupertius[1] maintained, that, in each seed parts exist adapted for the formation of every organ of the body, and that, at the time of the union of the seed in a fecundating copulation, each of the parts is properly attracted and aggregated by a kind of crystallization.[2]

The celebrated hypothesis of the eloquent and enthusiastic Buffon[3] is but a modification of the Hippocratic doctrine of epigenesis. According to him, there exist in nature two kinds of matter,—living and dead; the former perpetually changing during life, and consisting of an infinite number of small, incorruptible particles or primordial monads, which he called *organic molecules*. These molecules, by combining in greater or less quantity with dead matter, form all organized bodies; and without undergoing destruction are incessantly passing from vegetables to animals in the nutrition of the latter, and are returned from the animal to the vegetable by the death and putrefaction of the former. These organic molecules, during the period of growth, are appropriated to the developement of the individual; but as soon as he has acquired his full size the superfluous molecules are sent into depot in the genital organs, each molecule being invested with the shape of the part sending it. In this way, he conceived, the seed of both sexes is formed of molecules obtained from every part of the system. In the commixture of the seeds during a fecundating copulation,

[1] Vénus Physique, Paris, 1751.
[2] Adelon, Physiologie de l'Homme, iv. 85, 2de édit., Paris, 1829.
[3] Histoire Naturelle, tom. xvii., &c., Paris, 1799.

the same force that assimilates the organic molecules to the parts of the body for their nourishment and increase causes them to congregate for the formation of the new individual; and according as the molecules of the male or female predominate, so is the embryo male or female.

The ingenuity of this doctrine was captivating; and it appeared so well adapted for the explanation of many of the phenomena of generation, that it had numerous and respectable votaries. It accounted for the circumstance of procreation not being practicable until the system has undergone its developement at puberty. It explained why excessive indulgence in venery occasions emaciation and exhaustion; and why, on the other hand, the castrated animal is disposed to obesity,—the depot having been removed by the mutilation. The resemblance of the child to one parent rather than to the other was supposed to be owing to the one furnishing a greater proportion of organic molecules than the other; and as more males than females are born, the circumstance was ascribed to the male being usually stronger, and therefore furnishing a stronger seed, or more of it.

Prior to this hypothesis, Leeuenhoek[1] had discovered what he considered to be spermatic animalcules in the semen; but Buffon contested their animalcular nature, and regarded them as his vital particles or organic molecules; whilst he looked upon the ovarian vesicle as the capsule that contains the sperm of the female. The opinions of Buffon were slightly modified by Blumenbach[2] and Darwin.[3] The former, like Buffon, divided matter into two kinds, possessing properties essentially different from each other;—the inorganic and the organized; the latter possessing a peculiar creative or formative impulse, which he termed Bildungstrieb or *nisus formativus*,—a principle in many respects resembling gravitation, and endowing every organized tissue with a *vita propria.* This force, he conceived, presides over the arrangement of materials furnished by the sexes in generation. Darwin preferred to the term "organic molecules" that of *vital germs*, which, he maintains, are of two kinds, according as they are secreted or provided by male or female organs, whether animal or vegetable. In the subdivision, however, of the germs he retained the term *molecule;* but limited it to those of the female;—the vital germs or particles, secreted by the female organs of a bud or flower, or the female particles of an animal, being denominated by him *molecules* with formative propensities; whilst those secreted from the male organs he termed *fibrils* with formative appetencies. To the fibrils he assigned a higher degree of organization than to the molecules. Both, however, have a propensity or appetency to form or create, and "they reciprocally stimulate and embrace each other and instantly coalesce; and may thus be popularly compared to the double affinities of chemistry."

Subtile as are these hypotheses, they are open to forcible objections, of which a few only will suffice. The notion of this occult force is identical with that, which has prevailed in regard to life in general,

[1] Arcana Naturæ, Lugd. Bat., 1685.

[2] Ueber den Bildungstrieb, Götting., 1791; Comment. Societat. Götting., tom. viii.; and Institutiones Physiologicæ, sect. xl. p. 459. Götting., 1798.

[3] Zoonomia, vol. ii. sect. xxxix., 8, 10, 3d edit., London, 1801.

and leaves the subject in the same obscurity. What do the terms *plastic*, *cosmic*, or *vegetative force*, or Bildungstrieb express, which is not equally conveyed by *vital force*,—that mysterious power, on which so many unfathomable processes of the animal body are dependent, and of the nature or essence of which we know absolutely nothing? The objection, urged against the doctrine of Hippocrates,—that we have no evidence of the existence of female sperm,—applies equally to the hypotheses that have been founded upon it; and even were we to grant, that the ovarium is a receptacle for female sperm, the idea, that such sperm is constituted of organic molecules derived from every part of the body would still be gratuitous. We have no facts to demonstrate the affirmative; whilst there are many circumstances, that favour the negative. A person, for example, who has lost some part of his person—nose, eye, or ear, or has had a limb amputated, or been circumcised—still begets perfect children. Whence can the molecules, in such cases, have been obtained? It is true, that if the mutilation affect but one parent, the organic molecules of the lost part may still exist in the seed of the other; but we ought, at least, to expect the part to be less perfectly formed; which is not the case. Where two docked horses are made to engender, the result ought, *à fortiori*, to be imperfect, as the organic molecules of the tail could not be furnished by either parent, yet we find the colt in such cases, perfect in this appendage. An elucidative case is afforded by the fœtus. If we admit the possibility of organic molecules constituting those parts that exist in the parents, how can we account for the formation of such as are peculiar to fœtal existence? Whence are the organic molecules of the umbilical cord, or umbilical vein, or ductus venosus, or ductus arteriosus, or umbilical arteries obtained? These and other objections have led to the abandonment of the theory of Buffon, which remains a monument of the author's ingenuity and elevation of fancy, —not of his solidity.

2. *Evolution.*—According to this theory, the new being pre-exists in some shape in one sex, but requires to be vivified by the other in the act of generation; after which it commences a series of developements or *evolutions*, which lead to the formation of an independent being. The great differences of sentiment that have prevailed under this view have been as regards the part, which each sex has been conceived to play in the function. Some have considered the germ to exist in the ovary, and to require the vivifying influence of the male sperm to cause its evolution. Others have conceived the male sperm to contain the rudiments of the new being, and the female to afford it merely a nidus, and pabulum during its developement. The former class of physiologists have been called *ovarists* or *ovists*;—the latter *spermatists*, *seminists*, and *animalculists*. The ovarists maintain, that the part furnished by the female is an ovarian ovum, which, they conceive, is formed of an embryo and particular organs for its nutrition and first developement;—the embryo adapted for becoming, after a series of changes or evolutions, a being similar to the one whence it has emanated. This hypothesis was suggested by the fact, that in many animals a single individual only is necessary for reproduction, and its being easier, perhaps, to conceive this individual to be female than

male; as well as by what is noticed in many oviparous animals. In them, the part, furnished by the female, is manifestly an ovum or egg; and in many, such egg is laid before the union of the sexes; and fecundated externally. By analogy, the inference was drawn, that this may happen to the viviparous animal likewise. The notion is said, but erroneously, to have been first advanced by Joseph de Aromatariis.[1] It was developed by Harvey,[2] who strenuously maintained the doctrine —*omne vivum ex ovo.* The anatomical examinations of Sylvius, Vesalius, Fallopius, De Graaf,[3] Malpighi,[4] Vallisnieri[5] and others,—by showing, that what had been previously regarded as female testes, and had been so called, were organs containing minute vesicles or ova, and hence termed by Steno *ovaria,*—were strong confirmations of this view, and startling objections to the ancient theory of epigenesis; and the problem appeared to be demonstrated, when it was discovered, that the vesicle or ovum leaves the ovary and passes through the Fallopian tube to the uterus.

The chief arguments that have been adduced in favour of the doctrine are:—*First.* The difficulty of conceiving the formation, *ab origine*, of an organized body, as no one part can exist without the simultaneous existence of others. *Secondly.* The presence of the germ in many living beings prior to fecundation. In plants, for example, the grain exists in a rudimental state in the flower, before the pollen, which has to fecundate it, has attained maturity. In birds, too, the egg must preexist, as we find that those, which have never had intercourse with the male, can lay. This is more strikingly manifest in many fishes, and in the *batracia* or frog kind, where the egg is not fecundated until after it has been extruded. Spallanzani, moreover, asserts, that he could distinguish the presence of the tadpole in the unfecundated ova of the frog; and Haller, that of the chick in the infecund egg: he has seen them containing the yolk, which, in his view, is but a dependence of the intestine of the fœtus, and if the yolk exist, the chick, he argues, must exist also.[!] *Thirdly.* The fact, before referred to, that in certain animals, a single copulation is capable of fecundating several successive generations. In these cases, it is argued, the germ of the different generations must have existed in the first. *Fourthly.* The fact of natural and accidental encasings, inclusions or *emboîtements,*—as in the bulb of the hyacinth, in which the rudiments of the flower are distinguishable; in the buds of trees, in which the branches, leaves, and flowers, have been detected in miniature, and greatly convoluted; in the jaws of certain animals, in which the germs of different series of teeth can be detected; in the volvox, a transparent animal, which exhibits several young encased in each other; in the common egg, which occasionally has another within it; and in the instances on record, in which a human fœtus has been found encased—*fœtus in fœtu*—many cases of which are referred to by Professor Vrolik;[6] and of which there is a striking

[1] Epist. de Generatione Plantarum ex Seminibus, Venet., 1625.
[2] Exercitationes de Generatione Animalium, Lond., 1651.
[3] De Organis Mulierum, &c., Lugd. Bat., 1672.
[4] Append. ad Opera Omnia, Ludg. Bat., 1687.
[5] Istoria della Generazione dell'Uomo, Discorsi Acad. i.–iv., Venez., 1722–1726.
[6] Art. Teratology, in Cyclopædia of Anat. and Physiology, iv. 967, London, 1852.

example in a youth in the Museum of the Royal College of Surgeons, of London; and a similar one, in a boy fourteen years of age, has been recorded by Dupuytren. A most singular case of the kind occurred to M. Velpeau.[1] A tumour was removed from the scrotum of a young man aged 27, which was found to contain almost all the elements of a human body. Its exterior was evidently tegumentary, and the greater part of its substance, a mixture of lamellæ and fibres like areolar, adipous, muscular, and fibrous tissues. In the interior, there were two cysts filled with a substance like albumen or the vitreous humour; another cyst, as large as a partridge's egg, containing a greenish semi-fluid matter like meconium; and a fourth contained a dirty yellow grumous mass surrounded by hairs: the mass consisted of sebaceous matter and scales of epidermis; the hairs had no bulbs. A tuft of hair, which protruded externally from a kind of ulcer at the posterior part, —and which, with the fact of the tumor being congenital, induced M. Velpeau to consider it to be fœtal,—proceeded from the cyst that contained the meconium-like substance, and gave the opening into it somewhat the appearance of an anus. In the midst of all these, numerous perfectly organized portions of a skeleton were found, consisting of bones resembling more or less the clavicle, scapula, humerus, sphenoid bone, sacrum, portions of vertebræ, and others whose names could not be determined. A peculiarity of this case of monstrosity by inclusion was, that the second fœtus did not act as a foreign body in the other, but had a separate and independent existence and power of growth within itself. The tumour had its own colour and consistence, and a sensibility entirely independent of the person to whom it was attached. The man himself pierced it several times with a knife without feeling the least pain; and yet, all the wounds that were made in it bled, inflamed and cicatrized like those of any other part of the body.

Perhaps, the explanation of these extraordinary cases by Dr. Blundell[2] is as philosophical as any that could be devised. A seed or egg, though fecundated, may lie for years without being evolved. A serpent may become enclosed under the eggshell of the goose; the shell probably forming over it as the animal lies in the oviduct of the bird. These facts Dr. Blundell applies to the phenomenon in question. When the boy was begotten, a twin was begotten at the same time,—but, while the former underwent his developement in the usual manner, the impregnated ovum of his companion lay dormant, and unresistingly became closed up within the fraternal structure, as the viper in the eggshell. For a few years, these living rudiments generally lie quiet within the body, and ultimately become developed so as to occasion the death of both. "The boy," he remarks—speaking of one of the cases—"became pregnant with his twin brother; his abdomen formed the receptacle, where, as in the nest of a bird, the formation was accomplished." Cases of this kind of arrest of developement occasionally occur, where two or more ova are fecundated at the same time, or in succession. To this we shall refer under Superfœtation. *Fifthly.*

[1] Gazette Médicale, 15 Fév., 1840.

[2] Principles and Practice of Obstetricy, edited by Dr. Castle, London, 1834; American edition, Washington.

The fact of the various metamorphoses that take place in certain animals. Of these we have the most familiar instances in the batracia, and in insects. The forms which they have successively to assume are evidently encased within each other. In the chrysalis, the outlines of the form of the future butterfly are apparent; and in the larva we observe those of the chrysalis. The frog is apparent under the skin of the tadpole. *Sixthly.* The fact of artificial fecundation, which has been regarded by the ovarists as one of the strongest proofs of their theory;—the quantity of sperm employed, as in the experiments of Spallanzani already detailed, being too small, in their opinion, to assist in the formation of the new individual, except as a vivifying material. *Lastly.* They invoke the circumstance of partial reproduction, of which all living bodies afford more or less manifest examples;—as that of the hair and nails of man; the teeth of the rodentia; the tail of the lizard; the claw of the lobster; the head of the snail, &c., &c. All these phenomena, according to them, are owing to each part possessing within itself germs destined for its reproduction; and requiring only favourable circumstances for their developement. The partisans of the doctrine of epigenesis, however, consider these last facts as opposed to the views of the ovarists; and maintain, that, in such cases, there is throughout a fresh formation.

The chief objections, that have been urged against the hypothesis of the ovarists, are:—*First.* The resemblance of the child to the father —a subject to be referred to presently. The ovarists cannot of course deny that such resemblance exists; and they ascribe it to the modifying influence exerted by the male sperm; but without being able to explain the nature of such influence. They affirm, however, that the likeness to the mother is more frequent and evident. But certain cases of resemblance are weighty stumbling-blocks to ovism or the doctrine of a pre-existing germ in the female. It is a well-known fact, that six-fingered men occasionally beget six-fingered children. How can we explain this upon the principle of the pre-existence of the germ in the female, and of the part played by the male sperm being simply that of vivifying? and must we suppose, in the case of monstrosities, that such germs were originally monstrous? *Secondly.* The production of *hybrids* is one of the strongest counter-arguments. They are produced by the union of the male and female of different species. Of these, the mule is the most familiar instance,—the product of the ass and the mare. It strikingly participates in the qualities of both parents; and, consequently, the pre-existing germ in the female must have been more than vivified by the sexual intercourse. Its structure must have been altogether changed, and all the germs of its future offspring annihilated, for the mule is seldom fertile. If a white woman marries a negro, the child is a mulatto; and if the successive generations of this be united to negroes, the progeny will ultimately become entirely black; or, at least, the white admixture will be so small as to escape recognition. As a general rule, the offspring of different races has an intermediate tint between that of the parents. The proportions of white and black blood, in different admixtures, have even been subjected to calculation, in countries where negroes are common. The

following table represents these proportions, according to principles sanctioned by custom:—

Parents.	Offspring.	Degrees of Mixture.			
Negro and white,	mulatto,	$\frac{1}{2}$	white,	$\frac{1}{2}$	black.
White and mulatto,	terceron,	$\frac{3}{4}$	—	$\frac{1}{4}$	—
Negro and mulatto,	griffo, griff, or zambo, or black terceron,	$\frac{1}{4}$	—	$\frac{3}{4}$	—
White and terceron,	quarteron, quadroon,	$\frac{7}{8}$	—	$\frac{1}{8}$	—
Negro and terceron,	black quarteron or quadroon,	$\frac{1}{8}$	—	$\frac{7}{8}$	—
White and quarteron	quinteron,	$\frac{15}{16}$	—	$\frac{1}{16}$	—
Negro and quarteron,	black quinteron,	$\frac{1}{16}$	—	$\frac{15}{16}$	—

The last two, in the British West India Islands,[1] are considered to be respectively white and black; and the former were white by law, and consequently free, when slavery existed there. The following table is given by Tschudi[2] to exhibit the parentage of the different varieties of half casts, and their proper designations:—

Parents.	Children.
White father and negro mother,	mulatto.
White father and Indian mother,	mestizo.
Indian father and negro mother,	Chino.
White father and mulatto mother,	cuarteron.
White father and mestiza mother,	creole (only distinguished from the white by a pale brownish complexion).
White father and China mother,	Chino-blanco.
White father and cuarterona mother,	quintero.
White father and quintera mother,	white.
Negro father and mulatto mother,	zambo-negro.
Negro father and mestiza mother,	mulatto-oscuro.
Negro father and China mother,	zambo-Chino.
Negro father and zamba mother,	zambo-negro (perfectly black).
Negro father and cuarterona or quintera mother,	mulatto (rather dark).
Indian father and mulatto mother,	Chino-oscuro.
Indian father and mestiza mother,	mestizo-claro (frequently very beautiful).
Indian father and China mother,	Chino-cholo.
Indian father and zamba mother,	zambo-claro.
Indian father and China-chola mother,	Indian (with rather short frizzy hair).
Indian father and cuarterona or quintera mother,	mestizo (rather brown).
Mulatto father and zamba mother,	zambo (a miserable race).
Mulatto father and mestiza mother,	Chino (of rather clear complexion).
Mulatto father and China mother,	Chino (rather dark).

All these cases exhibit the influence exerted by the father upon the character of the offspring, and are great difficulties in the way of supposing, that the male sperm is simply a vivifier of the germ pre-existing in the female.

Thirdly. The doctrine of the ovarists does not account for the greater degree of fertility of cultivated plants and domesticated animals. *Fourthly.* The changes, induced by the succession of ages on the animal and vegetable species inhabiting the surface of the globe, have been adduced against this hypothesis. In examining the geological character of the various strata that compose the earth, it has been

[1] Lawrence, Lectures on Physiology, Zoology, and Natural History of Man, p. 299, Lond., 1819.

[2] Travels in Peru, during the years 1838–1842; translated from the German by Thomasine Ross, Amer. edit., p. 81, New York, 1847.

observed by geologists, that many of these contain embedded the fossil remains of animals and vegetables. Now the rocks on which others rest are the oldest, and the successive strata above these are more and more modern; and it has been found, that the organic fossil remains in the different strata differ more and more from the present inhabitants of the surface of the globe in proportion to the depth we descend; and that the remains of those beings, that have always been the companions of man, are found only in the most recent of the alluvial deposits,—the upper crust of the earth. It was an opinion, at one time universally embraced, that geological evidence is in favour of animals having been created in the order of their relative perfection, so that the lowest animals; as the polyps and echinoderms occupied the most ancient formations; and to these succeeded the mollusks; then the articulated animals, and, lastly, the vertebrate. More recent investigation has, however, satisfied the geologist, that fossils, belonging to each of the four departments, have been found in the fossiliferous deposits of every age. Four ages of nature, according to Professor Agassiz,[1] may be distinguished, which correspond with the great geological divisions. *First.* The *Primary* or *Paleozoic age*, comprising the lower Silurian, the upper Silurian, and the Devonian; during which there were no air-breathing animals. Fishes were the masters of creation, and hence—it has been suggested—this may be called the *Reign of Fishes*. *Secondly.* The *secondary age*, comprising the carboniferous formation, the trias, the oölitic, and the cretaceous formations, in which air-breathing animals first appear; and as the reptiles predominate over the other classes, this has been termed the *Reign of Reptiles*. *Thirdly.* The *Tertiary age*, comprising the tertiary formations, during which terrestrial mammals of great size abounded. This was the *Reign of Mammals;* and *Fourthly;* the *Modern age*, characterized by the appearance of the most perfect of all created beings. This has been called the *Reign of Man*.

In the older rocks the impressions are chiefly of the less perfect plants, and of the lower animals. In the more recent strata, the remains of reptiles, birds, and quadrupeds are apparent; but they differ essentially from existing kinds, and in none of the formations of more ancient date has the fossil human skeleton been met with. The skeleton of the savage Galibi, from Guadaloupe deposited in the British Museum, is embedded in a calcareous earth of modern formation; and the pretended human bones, conveyed by Spallanzani from the Island of Cerigo—the ancient Cythera—are not those of the human species, any more than the bones of the *Homo diluvii testis* of Scheuchzer. Hence it has been concluded, that man is of a date posterior to animals in all countries where fossil bones have been discovered. It has been attempted to explain these singular facts, furnished by modern geological inquiry, by the supposition, that the present races of animals are the descendants of those whose remains are met with in the rocks, and that their difference of character may have arisen from some change in the physical constitution of the atmosphere, or of the surface of the earth, producing a corresponding change in the forms of organized beings. It has been

[1] Agassiz and Gould, Principles of Zoology, p. 190, Boston, 1848.

properly remarked, however, by Dr. Fleming,[1] that the effect of circumstances on the appearance of living beings is circumscribed within certain limits, so that no transmutation of species was ever ascertained to have taken place, whilst the fossil species differ as much from the recent kinds as the last do from each other; and he adds, that it remains for the abettors of the opinion to connect the extinct with the living races, by ascertaining the intermediate links or transitions. This will probably never be practicable. The difference, indeed, between the extinct and living races is in several cases so extreme, that many naturalists have preferred believing in the occasional formation of new organized beings. Linnæus was bold enough to affirm, that, in his time, more species of vegetables were in existence than in former periods, and hence, that new vegetable species must necessarily have been ushered into being; and Wildenow embraced the views of Linnæus. De Lamarck,[2] one of the most distinguished naturalists of his day, openly professed the belief, that both animals and vegetables are incessantly changing under the influence of climate, food, domestication, crossing of breeds, &c., and he remarks, that if the species now in existence appear to us fixed in their characters, it is because the modifying circumstances require an enormous time for action, and would, consequently, require numerous generations to establish the fact. The manifest effect of climate, food, &c., on vegetables and animals, he thinks, precludes the possibility of denying those changes on theoretical considerations; and what we call *lost species* are, in his view, the actual species before they experienced modification. It is proper, however, to observe, that the representations on the wall of one of the sepulchres in the valley of Beban el Molook, at Thebes, which are regarded by Champollion as having been executed upwards of two thousand years before the Christian era, enable the features of the Jew and the negro, amongst others, to be recognized as easily as the representations of their descendants of the present day; so that, for the space of at least three thousand eight hundred years, no modification of the kind referred to by De Lamarck seems to have occurred in the human species.[3]

Another explanation has been offered for these geological facts, and for the rotation, which we observe in the vegetable occupants of particular soils in successive years. It has been supposed, that as the seeds of plants and the ova of certain animals are so excessively minute as to penetrate wherever water or air can enter; and as they are capable of retaining the vital principle for an indefinite length of time, of which we have many proofs, and of undergoing evolution whenever circumstances are favourable, the crust of the earth may be regarded as a receptacle of germs, each of which is ready to expand into vegetable or animal forms, on the occurrence of conditions necessary for their

[1] Philosophy of Zoology i. 26, Edinb., 1822.

[2] Philosophie Zoologique, edit. cit., tom. i., p. 218, Paris, 1830.

[3] "Nous avons sous les yeux des Momies Humaines; le squelette de l'homme d'aujourdhui est le même, absolument le même que le squelette de l'homme de l'antique Égypte. Ainsi donc, depuis deux ou trois mille ans, depuis les observations d'Aristote depuis les *momies* conservées d'Égypte, aucune espèce n'a changé." Flourens, De la Longévité Humaine et de la Quantité de Vie sur le Globe, 2de édit., p. 143, Paris, 1855.

developement. This is the hypothesis of *panspermia* or *dissemination of germs*, according to which the germs of the ferns and reeds were first expanded, and afterwards those of the staminiferous or more perfect vegetables; and, in the animal kingdom, first the polyp, and gradually the being more elevated in the scale; the organized bodies of the first period flourishing, so long as the circumstances favourable to their developement continued, and then making way for the evolution of their successors,—the changes effected in the soil by the growth and decay of the former probably favouring the evolution of the latter; which, again, retained possession of the soil so long as circumstances were propitious.[1] The changes that take place in forest vegetation are favourable to this doctrine. If, in Virginia, the forest trees be removed so as to make way for other growth, and the ground be prepared for the first cultivation, the *Phytolacca decandra* or *poke*, which was not previously perceptible on the land, usurps the surface. When Mr. Madison went with General Lafayette to the Indian treaty, they discovered, wherever trees had been blown down by a hurricane in the spring, that white clover had sprung up in abundance, although the spot was many miles distant from any cleared land; and it has often been remarked, that where, during a drought in the spring, the woods have taken fire, and the surface of the ground has been torrefied, the water-weed has made its appearance in immense quantities, and occupied the burnt surface. The late Judge Peters, having occasion to cut ditches on his land, in the western part of Pennsylvania, was surprised to find every subterranean tree met with differing from those occupying the surface at the time; and President Madison informed the author, that, in the space of sixty or seventy years, he had noticed the following spontaneous rotation of vegetables:—1. Mayweed; 2. Blue centaury; 3. Bottle-brush-grass; 4. Broom-straw; 5. White clover; 6. Wild carrot; and the last was then giving way to the blue grass.

The doctrine of panspermia is, however, totally inapplicable to the viviparous animal, in which the ovum is hatched within the body, and which, consequently, continues to live after the birth of its progeny; and the facts furnished by geology seem clearly to show, that the developement of the animal kingdom has been successive, not simultaneous; but under what circumstances the different animals were successively ushered into being, we know not.

Lastly, as regards the ovarists themselves;—they differ in essential points: whilst some are favourable to the doctrine of the *dissemination of germs*, believing, as we have seen, that ova or germs are disseminated over all space, and that they only undergo developement under favourable circumstances,—as when they meet with bodies capable of retaining them, and causing their growth, or which resemble themselves,—others assert, that the germs are enclosed in each other, and are successively aroused from their torpor, and called into life, by the influence of the seminal fluid; so that not only did the ovary of the first female contain the ova of all the children she had, but one only of these ova contained the whole of the human race. This was the celebrated system of *emboîtement des germes* or *encasing of germs*, already

[1] Fleming, op. citat., i. 28.

referred to, of which Bonnet[1] was the propounder, and Spallanzani the promulgator. Yet how monstrous for us to believe, that the first female had within her the germs of all mankind born, and to be born; or to conceive, that a grain of Indian corn contains within it all the seed, that may hereafter result from its culture. In this strange hypothesis—as Professor Elliotson[2] observes—there must have been an uncommon store of germs prepared at the beginning, for the ovaria of a single sturgeon have contained 1,467,500 ova.

Many of the ovarists, again, and they alone have any thing like probability in their favour, believe, that the female forms her own ova, as the male forms his own sperm, by a secretory action; and so far as the female is concerned in the generative process, we shall find that this is the only philosophical view; but it is imperfect in not admitting more than a vivifying action in the materials furnished by the male. The view formerly advanced by Bischoff,[3]—who now admits the positive entrance of the spermatozoid into the ovum[4]—that the spermatozoids act in a catalytic manner,—a certain internal movement being transferred from them to the molecules of the ova, which previously remained dormant,—appears to be liable to the same objections.

About the middle of the seventeenth century, Hamme or Van Hammen, Leeuenhoek[5] and Hartsöker,[6] discovered a prodigious number of small moving bodies in the sperm of animals, which they regarded as animalcules. This gave rise to a new system of generation, *ab animalculo maris*,—directly the reverse of that of Harvey. As, in the Harveian doctrine, the germ was conceived to be furnished by the mother, and the vivifying influence to be alone exerted by the male; so, in this doctrine, the entire formation was regarded as the work of the father, the mother affording nothing more than a nidus, and appropriate pabulum for the homunculus or rudimental fœtus. The spermatic doctrine was soon embraced by Boerhaave, Keill, Cheyne, Wolff, Lieutaud, and others. The pre-existing germ was accordingly now referred exclusively to the male; and, by some, the doctrine of *emboîtement* or encasing was extended to it. Nor is the view abandoned at the present day; for a recent writer[7] has maintained, that "the male furnishes the germ; and the female supplies it with nutriment, during the whole period of its early developement."

In support of this hypothesis, the spermatists urged,—that the animalcules they discovered were peculiar to the semen, and that they exist in the sperm of all animals capable of generation; that they differ in different species, but are always identical in the same animal, and in individuals of the same species;—that they are not perceptible in the sperm of any animal until the age at which generation is practicable, and are wanting in infancy and decrepitude;—that their number is so considerable, that a drop of the sperm of a cock, scarcely

[1] Considérat. sur les Corps Organisés, Amst., 1762.
[2] Blumenbach's Physiology, by Elliotson, 4th edit., p. 494, Lond., 1828.
[3] Muller's Archiv. für Anat., No. v. S. 436, Berlin, 1847. [4] Page 438.
[5] Oper., iii. 285, and iv. 169, Lugd. Bat., 1722.
[6] Journal des Sçavans, pour 1678; and Essai de Dioptrique, p. 227, Paris, 1694.
[7] Carpenter, Principles of Human Physiology, 4th Amer. edit., p. 720, Philad., 1850.

equal in size to a grain of sand, contains 50,000;—and lastly, that their minute size is no obstacle to the supposition, that generation is accomplished by them,—the disproportion between the trees of our forest and the seed producing them being nearly, if not entirely, as great as that between the animalcule and the being it has to develope. Leeuenhoek estimated the dimensions of those of the frog at about the 1-10,000th part of a human hair, and that the milt of a cod may contain 15,000,000,000,000,000 of them.

The difficulty with the spermatists or animalculists was to determine the mode in which the homunculus attains the ovary, and effects the work of reproduction. Whilst some asserted it to be only requisite, that the sperm should enter the uterus, and attract the ovum to it from the ovarium; others imagined, that the animalcule travelled along the Fallopian tube to the ovary; entered one of the ovarian vesicles; shut itself up there for some time, and then returned into the cavity of the uterus, to undergo its first developement through the medium of the nutritive substance contained in the vesicle; and a celebrated pupil of Leeuenhoek even affirmed, that he not only saw these animalcules under the shape of the tadpole, as they were generally described, but that he could trace one of them, bursting through the envelope that retained it, and exhibiting two arms, two legs, a human head and a heart![1]

This doctrine was extremely captivating; and, for a time, kept the minds of many eminent philosophers in a state of delusive enthusiasm; so much so, that Dr. Thomas Morgan,[2] in a work published in 1731, thus expresses himself regarding it:—"That all generation is from animalculum pre-existing in *semine maris*, is so evident in fact, and so well confirmed by experience and observation, that I know of no learned men, who in the least doubt of it." It was soon, however, strongly objected to by many; and the great fact on which it rested—the very existence of spermatic animalcules was, and—we have seen—is, strenuously contested. Linnæus[3] discredited the observations of Leeuenhoek. Verheyen denied the existence of the animalcules, and undertook to demonstrate, that the motion, supposed to be traced in them, was a mere microscopic delusion:—whilst Needham[4] and Buffon regarded them as organic molecules. Subsequently, MM. Prévost and Dumas[5] directed their attention to the subject; and their investigations, as on every other topic of physiological inquiry, are worthy of the deepest regard. The results of their examinations led them to confirm the existence of these animalcules, and likewise to consider them as direct agents in fecundation. By means of the microscope they detected them in all the animals, whose sperm was examined by them; and these were numerous. Whether the fluid was observed after its excretion by a living animal, or after death, in the vas deferens or the testicle, animalcules were detected in it with equal facility. They consider

[1] Adelon, Physiologie de l'Homme, edit. cit., iv. 94.
[2] Mechanical Practice of Physic, Lond., 1731.
[3] Bostock's Physiology, 3d edit., p. 643, Lond., 1836.
[4] New Microscopical Discoveries, Lond., 1745.
[5] Mém. de la Société Physique de Genève, i. 180, and Annales des Sciences Naturelles, tom. i. and ii.

these bodies to be characteristic of the sperm, as they found them only in that secretion,—being wanting in every other humour of the body, even in those that are excreted with the sperm, as the fluids of the prostate, and glands of Cowper; and although similar in shape, and size, and in the character of their locomotion in individuals of the same species, they are of various shapes and dimensions in different species. In passing through the series of genital organs they experience no change, being as perfect in the testicle as at the time of their excretion; and the remark of Leeuenhoek, that they are met with apparently of different ages, is unfounded. They were manifestly endowed with spontaneous motion, which gradually ceased, in the course of two or three hours, in the sperm obtained during life by ejaculation,—in that taken from the vessels after death, in fifteen or twenty minutes,—and in that left in its vessels after death, in eighteen or twenty hours. In farther proof of the position, that these presumed animalcules are the fecundating agents, MM. Prévost and Dumas assert, that they are only met with whilst reproduction is practicable;—that, in the human species, they are not found in infancy or decrepitude; and, in the majority of birds, are only apparent in the sperm at periods fixed for their copulation;—facts which, in their opinion, show, that they are not mere infusory animalcules. MM. Prévost and Dumas affirm, moreover, that they appear to be connected with the physiological condition of the animal furnishing them;—their motions being rapid or languishing, according as it is young or old, or in a state of health or disease. They state, also, that in their experiments on the ova of the mammiferous animal, they observed animalcules filling the cornua of the uterus, and remaining there alive and moving, until the ovule descended into that organ, when they gradually disappeared; and in favour of the influence of these animalcules they urge—that the positive contact of sperm is necessary for fecundation, and that the aura seminis is totally insufficient;—that the sperm, in twenty-four hours, loses its fecundating property, and it requires about this length of time for the animalcules to gradually cease their movements and perish;—and, lastly, that having destroyed the animalcules in the sperm, it lost its fecundating property. One of these experiments consisted in killing all the animalcules in a spermatized fluid, whose fecundating power had been previously tested, by repeated discharges of a Leyden phial: another consisted in placing a spermatized fluid on a quintuple filter, and repeating this until all the animalcules were retained on the filter; when it was found, that the fluid that passed through had no fecundating power, whilst the portion retained by the filter had; a result which had been obtained by Spallanzani, who found, moreover, that he was capable of effecting fecundation with water in which the papers employed as filters had been washed.

M. Donné[1] has investigated the mode in which the *zoospermes* are affected in blood, milk, the vaginal and uterine mucus in the healthy state, the purulent matter of chancres, and of blennorrhœa, in saliva, urine, &c. He observed them continue to live, and move in certain of those fluids; whilst in others they died instantaneously. For instance,

[1] Gazette Médicale de Paris, No. xxii., 3 Juin, 1837; and Cours de Microscopie, p. 291, Paris, 1845.

blood, milk and pus did not affect them: in the mucus of the vagina and uterus they generally lived well; but in saliva and urine they died almost instantaneously. He affirms, too, that there are cases in which the mucus of the vagina and uterus acquires properties that are deleterious to them, and is of opinion, that this is one cause of sterility. This deleterious property, according to M. Donné, occasionally resides in the vaginal mucus; but at others, in a still higher degree, in the mucus of the uterus: he endeavoured to discover, whether the mucus of the two membranes presented any peculiar characters or signs of disease, and states, that he particularly noticed the excessive acidity of the one, and the marked alkaline character of the other. Independently of its physical characters, the mucus secreted by the vagina as far as the orifice of the os uteri differed from that which flowed from within the cervix uteri by a different reaction. He found the vaginal mucus always acid,—the uterine alkaline, and he thinks, that the deleterious influence exerted on the *zoospermes* is dependent on excess of acid in the one, and of alkali in the other. All this, however, it need scarcely be said, requires substantiation. Professor Wagner,[1] who has entered at great length into the consideration of the spermatozoids, accords with the general conclusions of M. Donné: some of his experiments, however—instituted for the most part on the spermatozoids of the lower animals—led him to different conclusions. He found, for example, that they almost always lived in saliva; and in urine kept warm and not too concentrated. He repeatedly detected them in the urine of persons whom he suspected of masturbation. Dr. John Davy[2] states, that on examining the fluid from the urethra after stool in a healthy man, he always detected spermatozoids in it; and Dr. Robt. Willis,[3] under the same circumstances, and even after the mere evacuation of the bladder, several times discovered spermatozoids in the fluid of the urethra; but the subjects of his observations were never strong or healthy men: they mostly laboured under anomalous nervous symptoms, which, he thinks, were in all likelihood connected with an irritable or disordered state of the vesiculæ seminales and prostatic part of the urethra.

MM. Prévost and Dumas, and Rolando, conjecture, that the spermatozoids form the nervous system of the new being, and that the ovule furnishes only the areolar framework in which the organs are formed; but this is mere hypothesis. All that is demonstrated is the existence of those peculiar bodies in the sperm, and their manifest agency in the generative process; and it is scarcely necessary to remark, that every objection urged against the system of the ovarists, as regards the proofs in favour of an active participation of both sexes in the work of reproduction, are equally applicable to the views of those who refer generation exclusively to the spermatozoids.[4]

Such are the chief theories that have been propounded on the subject of generation. It has been already observed, that the particular

[1] Elements of Physiology, translated by Dr. Willis, p. 20, Lond., 1841.
[2] Edinburgh Medical and Surgical Journal, vol. i.
[3] Wagner, op. citat., p. 21 (note).
[4] For a history of opinions in regard to the agency of the sperm, see Coste, Histoire Générale et Particulière du Développement des Corps Organisés, p. 335, Paris, 1849.

modifications are almost innumerable. They may all, however, be classed, with more or less consanguinity, under some of the doctrines enumerated. Facts and arguments are strongly against any view that refers the whole process of formation to either sex.[1] There must be a union of materials furnished by both, otherwise it is impossible to explain the similarity in conformation to both parents, which is often so manifest. Accordingly, this modified view of epigenesis is now adopted by most physiologists;—that at a fecundating copulation, the secretion of the male is united to a material, furnished by the ovary of the female;—that from the union of these elements the embryo results, impressed, from the very instant of such union, with life, and with an impulse to a greater or less resemblance to this or that parent, as the case may be; and that the material furnished by the female is as much a secretion resulting from the peculiar organization of the ovary, as the sperm is from that of the testicle,—life being susceptible, in this manner, of communication from father to child, without there being a necessity for invoking the incomprehensible and revolting doctrine of the pre-existence of germs. This admixture of the materials furnished by both sexes accounts for the likeness that the child may bear to either parent, whatever may be the difficulty in understanding the precise mode in which each acts in the formation of the fœtus. It has been attempted, however, by some, to maintain, that the influence of the maternal imagination during a fecundating copulation may be sufficient to impress the germ within her with the necessary impulse; and the plea has been occasionally urged in courts of justice. Of this we have an example in a well-known case, tried in New York about fifty years ago. A mulatto woman was delivered of a female bastard child, which became chargeable to the authorities of the city. When interrogated, she stated that a black man of the name of Whistelo was the father, who was accordingly apprehended for the purpose of being assessed with the expenses. Several physicians, who were summoned before the magistrates, gave it as their opinion, that it was not his child, but the offspring of a white man. Dr. S. Mitchill, however, who, according to Dr. Beck, seemed to be a believer in the influence of the imagination over the fœtus, thought it probable that the negro was the father. Owing to this difference of sentiment, the case was carried before the mayor, recorder, and several aldermen. It appeared in evidence, that the colour of the child was somewhat dark, but lighter than the generality of mulattoes, and that its hair was straight, and had none of the peculiarities of the negro race. The court very properly decided in favour of Whistelo, and of course against the testimony of Dr. Mitchill, who, moreover, maintained, that as alteration of complexion has occasionally been noticed in the human subject,—as of negroes turning partly white,—and in animals, this might be a parallel instance.[2] The opinion does not seem, however, entitled to much greater estimation than that of the poor Irishwoman,

[1] See, on all this subject, Flourens, De la Longévité Humaine et de la Quantité de Vie sur le Globe, 2de édit., p. 174, Paris, 1855.

[2] Beck's Medical Jurisprudence, 6th edition, i. 500, Philad., 1838. For some ridiculous stories of this kind, see Demangeon, Du Pouvoir de l'Imagination sur la Physique et le Moral de l'Homme, p. 201, Paris, 1834.

in a London police report, who ascribed the fact of her having brought forth a thick-lipped, woolly-headed urchin to her having eaten some black potatoes during her pregnancy!

It is obvious, that the effect of the maternal imagination can only be invoked—by those who believe in its agency on the future appearance of the fœtus—in the case of animals in which copulation is a part of the process. Where the eggs are first extruded and then fecundated, all such influence must be out of the question; and as regards the viviparous animal we have seen that experiments on artificial impregnation have shown, not only that the bitch has been fecundated by sperm injected into the vagina, but that the resulting young have resembled the dog, whence the sperm had been obtained.[1]

But the strongest case in favour of the influence of the maternal imagination is given by Sir Everard Home.[2] An English mare was covered by a quagga,—*Equus quaccha*,—a species of wild ass from Africa, which is marked somewhat like the zebra. This happened in the year 1815, in the park of Earl Morton, in Scotland. The mare was only covered once; went eleven months, four days, and nineteen hours, and the produce was a hybrid, marked like the father. The hybrid remained with the dam for four months, when it was weaned and removed from her sight. She probably saw it again in the early part of 1816, but never afterwards. In February, 1817, she was covered by an Arabian horse, and had her first foal—a filly. In May, 1818, she was covered again by the same horse, and had a second. In June, 1819, she was covered again, but this year missed: in May, 1821, she was covered a fourth time, and had a third;—all being marked like the quagga. Haller[3] remarks, that the female organs of the mare seem to be corrupted by the unequal copulation with the ass, as the young foal of a horse from a mare, which previously had a mule by an ass, has something asinine in the form of its mouth and lips; and Becher[4] says, that when a mare has had a mule by an ass, and afterwards a foal by a horse, there are evidently marks, in the foal, of the mother having retained some ideas of her former paramour—the ass; whence such horses are commended on account of their tolerance and other similar qualities. It has even been affirmed, that the human female, when twice married, occasionally bears children to the second husband, which resemble the first in bodily structure and mental powers.[5] The mode in which the influence is exerted, in this and similar cases, is unfathomable; and the fact itself, although indisputable, astounding. Sir Everard Home[6] thinks, that it is one of the strongest proofs of the effect of the mind of the mother upon her young that has ever been recorded. Although we are totally incapable of suggesting any satisfactory solution, it appears more probable, that the impression must have been made on the genital system, and probably on the cells

[1] See page 427 of this volume.

[2] Philosoph. Transact. for 1821, p. 21; and Lectures on Comparative Anatomy, iii. 307.

[3] Element. Physiol., lib. xxix. sect. ii. § 10, Bern., 1766.

[4] Physic. Subterran., Lips., 1703.

[5] Art. Generation, by Dr. Allen Thomson, Cyclop. Anat. and Physiol., part xiii., p. 468, for Feb., 1838.

[6] Lectures, &c., iii. 308.

of nutrition of the ovaria, rather than on the mind of the animal. Yet it must be admitted, that even this explanation does not well account for a case, recorded by a recent writer.[1] When Dr. Hugh Smith, of England, was travelling in the country, the dogs, as is customary, ran out and barked as he passed through a village, and amongst these he observed a little ugly cur, "that was particularly eager to ingratiate himself with a setter bitch that accompanied him. While stopping to water his horse he remarked how amorous the cur continued, and how courteous the setter continued to her admirer." Provoked at the sight, he shot the cur, and carried the bitch on horseback for several miles. "From that day, however, she lost her appetite; ate little or nothing; had no inclination to go abroad with her master, or to attend to his call; but seemed to pine like a creature in love, and express sensible concern for the loss of her gallant. Partridge came; but Dido had no nose. Some time after, she was put to a setter of great excellence, which had, with great difficulty, been procured for the purpose; yet not a puppy did Dido bring forth, which was not the picture and colour of the cur, that the Doctor had, many months before, destroyed; and in many subsequent litters, Dido never produced a whelp that was not exactly similar to the unfortunate cur already mentioned!"

The whole of this subject, as well as that of hybridity, is full of interest to the physiologist, and has recently been subjected to fresh investigation. The case of the quagga is a striking one, and the more so as it occurred in animals of different species. Many cases, however, have been observed, in which mares, covered in every instance by different horses, brought forth foals, which always partook of the characters of the horse by which impregnation was first effected. In several foals in the Royal stud at Hampton Court, got by the horse Actæon, there were unequivocal marks of the horse Colonel,—the dams of these foals having been bred from by Colonel the previous year. Again; a colt, the property of the Earl of Sheffield, got by Laurel, so resembled another horse, Camel, that it was asserted at New Market, that he must have been got by Camel. It was ascertained, however, that the mother of the colt had been covered the previous year by Camel.[2] In the dog, sow, and cattle, these phenomena have been often observed; and facts have been brought forward to show, that the same thing may happen in the human species; but all observation sufficiently demonstrates that if it ever occurs it must be rare. Dr. Harvey[3] has given two cases in support of the view; one of them that of a woman who was twice married, and had issue by both husbands. The children of the first marriage were five in number; of the second, three. One of these three, a daughter, bears an unmistakable resemblance to her mother's first husband; and, what makes the likeness the more striking, there was the most marked difference between the two husbands in their features and general appearance.

The phenomena of hybridity have been referred to before. It is

[1] J. S. Skinner, The Dog and the Sportsman, p. 19, Philad., 1845.

[2] McGillivray, Aberdeen Journal, Mar. 28, 1849; quoted by Dr. Alexander Harvey, in Monthly Journal of Medical Science, Oct., 1849.

[3] Op. cit.

undoubtedly a general rule, that hybrids do not procreate. Buffon, Mr. Hunter, and others, indeed, considered the rule absolute; but it is not admitted to be a test of specific character. Dr. Morton[1] has enumerated various forms of hybridity in animals and plants; and has shown, that it occurs, not only amongst different species, but amongst different genera; and that the cross breeds have been prolific in both cases. There is great probability, that if animals were so situate, that the want of inclination for each other, or the natural repugnance could be overcome, so that sexual desire should arise, cases of hybridity would be much more frequent than they are. In the year 1848, a remarkable filly—seven months old—was found in the New Forest, England, which is evidently—from the sketch of it[2]—a mixed breed between the horse and the deer. The mother—a pony mare—was observed to associate with some red deer stags, and at length the foal in question was seen by her side. The nose shows an approximation both to the stag and the horse; the forehead is round like that of the deer; the legs are slender and distinctly double; and the hoofs pointed, and partly double; the colour is brown, light under the belly; and the tail is like that of the deer.

In cases of infertile or barren hybrids, there would appear to be a radical change produced in the germ-forming organs of both sexes. Of the modifications in the female genital system we know nothing. In the male, in many cases, no spermatozoids are found in the semen. Such has been shown to be the case with the mule by Bonnet, Prévost and Dumas, Hausmann and others; and the same thing has been observed in the hybrids of goldfinches and canary birds.[3] In others, real spermatozoids have been seen, but they were smaller than, and shaped differently from, the natural. The sperm of procreating hybrids does not appear to have been examined.

The fact, that various different species of animals are capable of producing a prolific hybrid is fatal—as Dr. Morton[4] has remarked—to the notion, that hybridity is "a test of specific affiliation; and, "consequently,"—he adds—"the mere fact, that the several races of mankind produce with each other a more or less fertile progeny, constitutes, in itself, no proof of the unity of the human species."

It has been a common opinion, not confined to the vulgar only, that the mulatto is not as fertile as the white or the negro; and the probable extermination of the two races has been suggested, if the whites and blacks were allowed to intermarry;[5] but the assertion can scarcely be esteemed to rest on sufficient actual observation. Were it so, it might be interesting to inquire, whether the infertility applies rather to the female than to the male. It would probably be found, that the former would be in fault. It is affirmed by an excellent and talented traveller,[6] with whom the author had the pleasure of a personal ac-

[1] Hybridity in animals and plants, considered in reference to the question of the unity of the human species, New Haven, 1847, from Amer. Journ. of Science and Arts, vol. iii., second series, 1847.

[2] Illustrated London News, Dec. 9, 1848.

[3] Art. Semen, Cyclopædia of Anatomy and Physiology, Pt. xxxiv. p. 508, Jan., 1849.

[4] Op. cit., p. 23.

[5] J. C. Nott, American Journal of the Medical Sciences, July, 1843, p. 252.

[6] P. E. de Strzelecki, Physical Description of New South Wales and Van Diemen's Land, p. 346, London, 1845.

quaintance in this country, that examinations among the oldest aborigines of every country render it evident "that their longevity has not been abridged; that the rate of mortality has not increased, but that the power of continuing or procreating the species appears to have been curtailed. On further inquiry, this curtailment of power was not found to originate with the male, so far at least as could be observed; but some startling facts, disclosed in the course of the investigation, seem to confine it to the female." Of these the most remarkable, according to Count Strzelecki, is, that whenever a union takes place between an aboriginal female and a European male, "the native female is found to lose the power of conception on a renewal of intercourse with the male of her own race, retaining only that of procreating with the white man." "Hundreds of instances"—he adds—"of this extraordinary fact are on record in the writer's memoranda, all tending to prove, that the sterility of the female being relative only to one, and not to another male,—and recurring invariably, under the same circumstances, amongst the Hurons, Seminoles, Red Indians, Yakies (Sinaloa), Mendoza Indians, Araucos, South Sea Islanders, and natives of New Zealand, New South Wales, and Van Diemen's Land,—is not accidental, but follows laws as cogent, though as mysterious, as the rest of those connected with generation."

These statements are worthy of attention, but they require fresh investigations before they can be regarded as established, especially as they certainly do not apply to the negro,—repeated opportunities occurring in this country and elsewhere to show, that the impregnation of a coloured woman by a white man does not deprive her of the power of subsequent procreation with an individual of her own race. They have, moreover, been contradicted, as regards the aboriginal females of Australia, by Dr. T. R. H. Thompson, R. N., who affirms, as the result of personal inquiries among several different tribes, that for a native female to bear children to a native male, after having borne half-caste children to a European father, is by no means an uncommon occurrence.[1]

d. *Conception.*

Conception usually takes place without the slightest consciousness on the part of the female; hence the difficulty of reckoning the precise period of gestation. Certain signs, as shivering, pains about the umbilicus, &c., are said to have occasionally denoted its occurrence; but they are rare exceptions, and the indications afforded by one female are often extremely different from those presented by another. In animals, in which generation is only accomplished during a period of generative excitement, the period of conception can be determined with accuracy; for, in by far the majority of such cases, a single copulation fecundates,—the existence of the state of *heat* indicating, that the generative organs are ripe for conception. In the human female, where sexual intercourse can take place at all periods, conception is by no means as likely to follow a single intercourse; for, although she

[1] Dr. Carpenter, art. Varieties of Mankind, in Cyclop. of Anat. and Physiol., iv. 1365, Lond., 1852.

may be always susceptible of fecundation, her genital organs are rarely, perhaps, so powerfully excited as in the animal during the season of love. It is not for the physiologist to inquire into the morbid causes of sterility in either male or female; nor is it desirable to relate all the visionary notions which have prevailed regarding the circumstances that favour conception. The ovarian conditions under which it is effected have already been canvassed under Fecundation.

It has been attempted to ascertain what age and season are most prolific. From a register kept by Dr. Bland, of London, it would appear, that more women bear children between the ages of twenty-six and thirty years, than at any other period. Of two thousand one hundred and two women delivered, eighty-five were from fifteen to twenty years of age; five hundred and seventy-eight from twenty-one to twenty-five; six hundred and ninety-nine from twenty-six to thirty; four hundred and seven from thirty-one to thirty-five; two hundred and ninety-one from thirty-six to forty; thirty-six from forty-one to forty-five; and six from forty-six to forty-nine. At Marseilles, according to Raymond, women conceive most readily in autumn, and especially in October; next in summer; and lastly in winter and spring,—the month of March having fewest conceptions. Morand says, that July, May, June, and August have the most; and November, March, April, and October, successively, the fewest. At the Havana, according to tables published by Don Ramon de la Sagra,[1] the monthly number of births, amongst the white population, during a period of five years,—from 1825 to 1829 inclusive—was in the following order:—October, September, November, December, August, July, June, April, May, January, March, and February. February, January, March, and April are, therefore, the most favourable for conception at the Havana; June, July, May, and September the least so. Dr. Burns[2] asserts, that the register for ten years of an extensive parish in Glasgow, renders it probable that August and September are most favourable. M. Villermé, from an estimate founded on eight years' observations in France, comprising 7,651,437 births, makes the ratio as follows:—May, June, April, July, February, March and December, January, August, November, September, and October:—and Dr. Gouverneur Emerson,[3] who has employed himself most profitably on the Medical Statistics of Philadelphia, has furnished a table of the number of births, during each month, for the ten years ending in 1830; according to which the numbers are in the following order:—December, September, January, March, October, August, November, February, July, May, April, and June,—the greatest number of conceptions occurring, consequently, in April, January, and May,—the least in October, August, and September.

The proportion will, of course, be regulated to a great extent by the time of marriage. In England,[4] the greatest number of these occurs in autumn, and consequently we should expect the ratio of births to be greatest in winter, which is the fact. The following table

[1] Historia Economico-Politica y Estadistica de la Isla de Cuba, Habana, 1833.
[2] Principles of Midwifery, 3d edit., p. 126, London, 1814.
[3] Amer. Journ. of the Med. Sciences, for Nov., 1831.
[4] Fifth Annual Report of the Registrar-General, &c., London, 1843.

shows the relative number of marriages, births, and deaths, in the seasons of the year, corrected for inequality of time.

	Autumn.	Spring.	Summer.	Winter.
Marriages, . . .	36,306	31,355	29,634	25,482
Births, . . .	131,257	129,677	121,053	120,356

The human female is uniparous,—one ovum only, as a general rule, being fecundated: numerous other animals are multiparous or bring forth many at a birth. The law on this subject is not fixed, however. Occasionally, the human female brings forth twins, triplets, or quadruplets; and the multiparous animal is not always delivered of the same number. It is impossible to account for those differences. The ovarists refer them to the female; the animalculists to the male; and facts have been found to support both views. Certain females, who have been frequently married, have been multiparous with each husband; and analogous facts have occurred to males under similar circumstances. Ménage cites the case of a man, whose wife brought him twenty-one children in seven deliveries; and the same individual having impregnated his servant-maid, she brought forth triplets likewise. It is asserted, that, in 1755, a peasant was presented to the Empress of Russia, who was seventy years of age, and had been twice married. His first wife had fifty-seven children at twenty-one births. In four deliveries she had four children at each; in seven, three; and in six, two. This appears to be the *ne plus ultra* of such cases!

In the *Hospice de la Maternité*, of Paris, it has been observed, that twins occur once in about eighty cases. In the Westminster Hospital, the same ratio has been found to prevail. In 1840, of 547,293 births in the kingdom of Prussia, 6,381 were twin cases, or 1 in 90. In the British Lying-in Hospital, the proportion was not greater than 1 in 91; whilst in the Dublin Lying-in Hospital, the cases were nearly twice as frequent, or about 1 in 57. Dr. Collins[1] remarks on the singular circumstance, that in Ireland the proportional number of women giving birth to twins, is nearly a third greater than in any other country of which he had been able to obtain authentic records. He states the proportion in France to be *one* in 95 births; in Germany, *one* in 80; in England, *one* in 92; in Scotland, *one* in 95; and in Ireland, *one* in 62. According to the report of Dr. Simpson,[2] in the Edinburgh Royal Maternity Hospital, of 1417 women delivered, 17, or 1 in 83, gave birth to twins. Of 129,172 women delivered in the Lying-in Hospital, Dublin, 2062 gave birth to twins; 29 produced three at a birth, which is in the proportion of *one* in 4450; and *one* only gave birth to *four*. In this country, the average of twin cases, according to Dr. Dewees, is about 1 in 75. Triplet cases were found to occur in the *Hospice de la Maternité*, of Paris, about once in 9000 times; and in the Dublin Hospital once in 5050 times; the balance, again, being largely in favour of the prolific powers of the Irish. Dr. Dewees affirms, that in more than 9000 cases, he had not met with an instance of triplets. Of 36,000 cases in the *Hospice de la Maternité* not one

[1] A Practical Treatise on Midwifery, London, 1835: republished in Bell's Select Library, Philad., 1838.

[2] Monthly Journal and Retrospect of the Medical Sciences, Nov. 1848, p. 334.

brought forth four children. In 1849, a woman, a native of Ireland, living in Southwark, Philadelphia, was delivered of four children,—all boys, each weighing about five pounds:—three of them were born alive. This woman, who was about 19 years of age, is said to have had six children by a former husband at three parturitions. At the first, she was delivered of a boy and a girl; at the second of a girl, and at the third of two boys and a girl. There are cases on record where five have been born. Beyond this number the tales of authors ought perhaps to be esteemed fabulous. The statistics of the Lying-in Hospital of Vienna and of Belgium, in reference to this subject, are given hereafter.[1]

On inspecting the following table, it will be found to be a general rule amongst quadrupeds, that the largest and most formidable bring forth the fewest young, and that the lower tribes are unusually fruitful,—the number produced compensating, in some measure, for their natural feebleness, which renders them constantly liable to destruction. On the other hand, were the larger species to be as prolific as the smaller, the latter would soon be blotted from existence. What would have been the condition of animated nature, if the gigantic mastodon, once the inhabitant of our plains, could have engendered as frequently and as numerously as the rabbit! For wise purposes, it has been ordained, that the more formidable animals seldom begin the work of reproduction until they have nearly attained their full size; whilst those that bring forth many commence much earlier. Lastly, there is some correspondence between the duration of gestation and the size of the animal.

Animals.	Duration of Gestation.	Number of Young.	Animals.	Duration of Gestation.	Number of Young.
Ape . .	about 9 months,	1	Lioness .	. . .	4 or 5
Bat . .	. . .	2	Tigress .	. . .	4 or 5
Rat . .	5 or six weeks,	5 or 6	Cat . .	8 weeks,	4 or 5
Mouse .	. . .	6 to 10	Seal . .	. . .	2
Hare . .	30 days,	4 or 5	Mare . .	11 months and some days,	1
Rabbit .	Do.	Do.			
Guinea-pig	3 weeks,	5 to 12			
Squirrel .	6 weeks,	4 or 5	Ewe . .	5 months,	1 or 2
Mole . .	. . .	4 or 5	Goat . .	$4\frac{1}{2}$ months,	1, 2, or 3
Bear . .	. . .	2 or 3	Cow . .	9 months,	1 or 2
Otter . .	9 weeks,	4 or 5	Reindeer.	8 months,	2
Bitch . .	9 weeks,	4 to 10	Hind . .	Do.	1 or 2
Ferret .	6 weeks,	6 or 7	Sow . .	4 months,	6 to 12 and more
Wolf . .	10 weeks,	5 to 9			
Opossum.	. . .	4 or 5	Camel .	12 months,	1
Kangaroo	. . .	1	Walrus .	9 months,	1
Jackall .	. . .	6 to 8	Elephant.	2 years,	1
Fox . .	10 weeks,	4 or 5	Whale .	9 or 10 months,	1 or 2

Conception being entirely removed from all influence of volition, it is obviously impracticable, by any effort of the will, either to modify the sex of the fœtus or its general physical and moral characters. Yet

[1] See, on all this subject, F. H. Ramsbotham, The Principles and Practice of Obstetric Medicine and Surgery, &c., Amer. edit. by Dr. W. V. Keating, p. 640, Philad., 1855.

idle and absurd schemes have been devised for both one and the other. The older philosophers, as Hippocrates and Aristotle, believed that the right testicle and ovary furnish the rudiments of males, and the same organs, on the left side, those of females: and some of the old writers, *de Re Rusticâ*, assert that such was the result of their experiments with the ram. These statements gave rise to a pretended "art of procreating the sexes at pleasure," which has been seriously revived in our own time. Mr. John Hunter published the details of an experiment in the "Philosophical Transactions," which was instituted for the purpose of determining, whether the number of young be equally divided between the ovaries. He took two sows from the same litter, deprived one of an ovary, and counted the number of pigs produced by each during its life. The sow with two ovaries had one hundred and sixty-two: the spayed one only seventy-six. Hence he inferred, that each ovary had nearly the same proportion. In this experiment, he makes no mention of the interesting fact—the proportion of the males in the two cases, and whether they were all of the same sex in the sow that had been spayed. Had his attention been drawn to this point, the results would doubtless have been sufficient to subvert the strange hypothesis brought forward by M. Millot,[1] that males are produced by the right ovary; females by the left; and the wild assertion, that he could so manage the position of the woman during copulation, that she should certainly have a boy or girl, as might have been determined upon; in confirmation of which he published the names of mothers, who had followed his advice, and succeeded to their wishes! A case, related by Dr. Granville, of London, to the Royal Society,[2] has completely exhibited the inaccuracy of this notion. A woman, forty years of age, died at the *Hospice de la Maternité* of Paris, six or seven days after delivery, of what had been supposed to be disease of the heart. The body was opened in the presence of Dr. Granville, and the disease was found to be aneurism of the aorta. On examining the uterus, it was discovered to be at least four times the size of the unimpregnated organ. It had acquired its full developement on the right side only, where it had the usual pyriform convexity; whilst the left formed a straight line scarcely half an inch distant from the centre, although it was more than two inches from the same point to the outline of the right side. The Fallopian tube and ovary, with the other parts on the right side, had the natural appearance; but *they were not to be found on the left.* Yet this woman had been the mother of eleven children of both sexes; and a few days before her death had been delivered of twins,—one male and one female.[3] M. Jadelot has given the dissection of a female, who had been delivered of several children—boys and girls; yet she had no ovary or Fallopian tube on the right side. M. Lepelletier[4] asserts, that he saw a similar case in the Hospital at Mans, in 1825; and the *Recueils* of the *Société de Médecine*, of Paris, contain the history of an extra-uterine gestation, in which a male fœtus was contained in the left ovary.

[1] L'Art. de Procréer les Sexes a Volonté; nouvelle édit., par M. Breschet, Paris, 1829.
[2] Philos. Transact. for 1808, p. 308.
[3] Sir E. Home, Lect. on Comp. Anat., iii. 300.
[4] Physiologie Médicale et Philosophique, iv. 333, Paris, 1833.

Independently of these decisive cases, it has been found, that when one of the ovaries has been entirely disabled by disease, the other has conceived of both sexes. In rabbits, an ovary has been removed; yet both male and female fœtuses have subsequently been engendered; and if the gravid uterus of one of those animals be examined, male and female fœtuses may be found in the same cornu of the uterus, all of which, owing to peculiarity of construction of the uterus,—the cornu forming the main part of the organ,—must manifestly have proceeded from the corresponding ovary. We are totally unaware, therefore, of the circumstances that give rise to the sex of the new being; although satisfied that it is in no respect influenced by the desires of the parents. We shall see, hereafter, that some distinguished physiologists believe, that the sex is not settled at the moment of conception, and that it is determined at a later period, after the embryo has undergone a certain degree of developement.

It is an ancient opinion, which seems to be in some measure confirmed by what we notice in certain animals, that the character of the offspring is largely dependent upon the moral and physical qualities of the parent; and a M. Robert, of Paris, in a dissertation under the pompous title of *Megalanthropogenesis*, has fancifully maintained, that the race of men of genius may be perpetuated by uniting them to women possessed of the same faculties. Similar views are maintained by Claude Quillet.[1] It is an old view, that the procreative energy of the parents has much to do with the mental and corporeal activity of the offspring. Hence it is, that bastards have been presumed to excel in this respect. Such is the view of Burton,[2] and the same idea is put, by Shakspeare, into the mouth of Edmund.

> "Why brand they us
> With base? with baseness? bastardy? base? base?
> Who in the lusty stealth of nature take
> More composition and fierce quality
> Than doth within a dull, stale, tired bed
> Go to the creating a whole tribe of fops
> Got 'tween sleep and wake!"—King Lear, i. 2.

Much doubtless, depends upon the condition of the parents as regards their organization and strength of constitution. The remark—"fortes creantur fortibus et bonis"—is true within certain limits; but we have no proof, that the ardour of the procreative effort can have any such influence; and the ratio of instances of bastards, who have been signalized for the possession of unusual vigour—mental or corporeal—to the whole number of illegitimates, is not greater than in the case of those born in wedlock. It has been stated that the number of male children is greater in cases of legitimate than of illegitimate births. Mr. Babbage[3] has compared the ratio in different countries, from which he has formed the following table:—

[1] Callipædia, sive de Pulchræ Prolis Habendæ Ratione, &c., Lond., 1708.
[2] Anatomy of Melancholy.
[3] Brewster's Journal of Science, New Series, No. 1.

	Legitimate Births.		Number of Births observed.	Illegitimate Births.		Number of Births observed.
	Females.	Males.		Females.	Males.	
France,	10,000	10,657	9,656,135	10,000	10,484	673,047
Naples,	10,000	10,452	1,059,055	10,000	10,267	51,309
Prussia,	10,000	10,609	3,672,251	10,000	10,278	212,804
Westphalia,	10,000	10,471	151,169	10,000	10,039	19,950
Montpellier,	10,000	10,707	25,064	10,000	10,081	2,735
Mean,	10,000	10,575		10,000	10,250	

Of 248,544 children registered in England,[1] 15,389 were illegitimate; so that 1 in 16 of the children born in England is not born in wedlock. In Austria, in the year 1843, 1 child in 4 was illegitimate; and in Vienna, 1 in 2.[2]

From the statistics of the Gebäranstalt, the Imperial Lying-in Hospital of Vienna, which is the great receptacle of illegitimate conceptions, it would seem that the number of female children born in it actually exceeds that of males. Of 21,212 children born there in the seven years prior to 1838, the sexes were in the proportion of 10,584 males to 10,628 females.[3] It is proper, however, to remark, that the Registrar-General found the reverse of this to be the fact in England.[4] Of the legitimate births, the boys were to the girls as 105·4 to 100·0; whilst of the illegitimate, they were as 108·0 to 100·0. "It is, I believe, assumed"—he remarks—"in the French returns, that foundling children are illegitimate. If it be true, as is stated by those acquainted with the matter, that many of the children sent to the foundling hospitals in France are the offspring of married people, who probably abandon a greater proportion of girls than boys, it will follow;—*first*, that the proportion of children born out of wedlock is nearly the same in England as in France; and, *secondly*, that the inference from the returns of Continental States having foundling hospitals as to the relative predominance of females among natural children is fallacious." It is obvious, that these authoritative statistical conclusions must make us pause before we can regard it as at all established, that the ratio of boys to girls is less amongst illegitimate than legitimate conceptions.

To elucidate the effect of the condition of the parent on the future progeny, M. Girou de Buzareingues[5] gave a violent blow to a bitch whilst lined; in consequence of which she was paraplegic for some days. She brought forth eight pups, all of which, except one, had the hind legs wanting, malformed, or weak. It has been attempted to show, also, that the corporeal vigour of the parents has much to do even with the future sex. M. Girou instituted a series of experiments on differ-

[1] Fifth Annual Report of the Registrar-General of Births, Deaths, and Marriages, in England, Lond., 1843.

[2] Knolz, Jahresbericht, u. s. w. in der Provinz Oesterreich unter der Enns, vom Jahre, 1843, S. xlix. Wien, 1844.

[3] Austria: its Literary, Scientific, and Medical Institutions, by W. R. Wilde, p. 22, note, Dublin, 1843.

[4] Fifth Annual Report, &c., Lond., 1843.

[5] Mémoire sur les Rapports des Sexes, &c., Paris, 1836; and a farther Memoir, in Revue Médicale, 1837.

ent animals, but especially on sheep, to discover, whether a greater number of male or female lambs may not be produced at the will of the agriculturist. The plan adopted to insure this result was to employ very young rams in that division of the flock where it was desired to obtain females; and strong and vigorous rams, of four or five years of age, in that from which males were to be procured. The result would seem to show, that the younger rams begat females in greater proportion; and the older, males. M. Girou asserts, that females commonly predominate amongst animals that live in a state of "polygamy," and it is affirmed, that the same fact has been observed, in Turkey and Persia, in the human species; but statistical data are wanting. These and other facts have seemed, however, to show, that in the act of generation, it is, as a general rule, the stronger individual that regulates the sex of the progeny. M. Moreau[1] has arrived at this conclusion as the result of long observation. He is of opinion, that, to a certain extent, a boy or girl may be begotten at will by strengthening or weakening the father or mother, previous to the act of generation; and he states, that by acting on this rule he has seen, in numerous instances, his advice followed by the desired results.

From the researches of Hofacker[2] and Sadler,[3] it would appear, that, as a general rule, when the mother is older than the father, fewer boys are born than girls, and the same is observed where they are of equal age; but the greater the excess of age on the part of the father, the greater will be the ratio of boys. The fact deduced from the observations of these gentlemen has been characterized by a recent writer as "one of the most remarkable contributions that have yet been made by statistics to physiology."[4] The following table gives the average results obtained by them; the numbers indicating the proportion of male births to 100 females.

	Hofacker.		Sadler.
Father younger than mother,	90·6	Father younger than mother,	86·5
Father and mother of equal age,	90·0	Father and mother of equal age,	94·8
Father older by 1 to 6 years,	103·4	Father older by 1 to 6 years,	103·7
6 to 9	124·7	6 to 11	126·7
9 to 18	143·7	11 to 16	147·7
18 and more,	200·0	16 and more,	163·2

Researches by Dr. Emerson,[5] have led him to the conclusion, that the extensive prevalence of every severe zymotic disease; and indeed any occurrence, which directly or indirectly exerts a decidedly depressing effect upon a community, will be indicated in the record of births by a conspicuous reduction in the proportion of males. The ordinary average excess of male births was found, by former calculations, to be, in Philadelphia, about 7 per cent.; and during the cholera months of August and September, 1832, the diminution of male conceptions was at the rate of more than 17 per cent.; and a similar diminution occurred in Paris, and other places, during the existence of the same malady.

[1] Edinb. Med. and Surg. Journ., Oct., 1844; from L'Expérience, 4 Juillet, 1844.
[2] Annales d'Hygiène, p. 537, July, 1829.
[3] The Law of Population, ii. 343, Lond., 1830.
[4] Carpenter, Human Physiology, § 771, Lond., 1842.
[5] American Journal of the Medical Sciences, for July, 1848, p. 78.

It appears, that the general proportion of males born to females is everywhere pretty nearly the same. The calculations of Hufeland give the numbers in Germany as 21 to 20; those of Girou, in France, as 21 to 19·69; and in Paris, 21 to 20·27; the census of Great Britain, taken in 1821, estimates it as 21 to 20·066, and the Registrar-General of England,[1] at 21 to 20·026. In the Dublin Lying-in Hospital during ten years, the ratio was 21 to 19·33; in the Eastern District of the Royal Maternity Charity, of London, during the year 1830, 21 to 19·64; and in the province of Austria, in the year 1823,[2] 21 to 20. In Philadelphia, according to the tables of Dr. Emerson,[3] the proportion from 1821 to 1830, was 21 to 19·43. In the whole of Europe it is estimated to be 21 to 19·81. Although, however, a greater number of males may be born, they seem more exposed to natural or accidental death; for amongst adults the balance is much less in their favour; and, indeed, the number of adult females rather exceeds that of the males. Dr. Emerson[4] states, that of the children born in Philadelphia during the ten years included between 1821 and 1830, amounting, according to the returns made to the Board of Health, to 64,642,— there were 2,496 more males than females. But, notwithstanding the males at birth exceeded the females about 7½ per cent., the census of 1830 shows, that by the fifth year, the male excess is reduced to about 5 per cent., and at ten years to only 1 per cent.; and that, the reduction still going on, the number of females between the ages of 10 and 15 exceeds that of the males about 8 per cent.; and between 15 and 20, 7·3 per cent.; facts, which clearly authorize the deduction of M. Quetelet,[5] that during the early stages of life there are agencies operating to reduce the proportion of the male sex. Dr. Emerson's investigations exhibit clearly, that the greater liability of males to accidents did not furnish a sufficient reason for their greater mortality;—the deaths reported in the Philadelphia bills, under the head of casualties, constituting but a small proportion of the whole mortality; and this— when burns and scalds are included—being more considerable in the case of the female. The gross male mortality under the twentieth year, for the ten years above mentioned, exceeded the female mortality in the ratio of 7·94 per cent. The diseases, which seemed to be particularly obnoxious to the male sex, were, according to the Philadelphia bills, the following—arranged in the order of their decreasing mortality:—inflammation of the brain, inflammation of the bowels, bronchitis, croup, inflammation of the lungs, fevers of all kinds (except scarlet), convulsions, general dropsy, dropsy of the head, and smallpox. To these sources of mortality may be added those under the head of casualties, and others vaguely designated debility, decay, &c. The few cases in which the deaths of females predominated were,—consumption, dropsy of the chest, scarlet fever, burns and scalds, and hooping-cough. In subsequent statistical researches on this interesting topic, Dr. Emer-

[1] Fifth Annual Report of the Registrar-General of Births, Deaths, and Marriages in England, Lond., 1843.

[2] Knolz, op. cit.

[3] Amer. Journ. of the Med. Sciences, for Nov., 1835.

[4] Ibid., for Nov., 1835, p. 56.

[5] Sur l'Homme, i. 156, Paris, 1835.

son[1] found, that in Philadelphia, the diseases, which prove especially fatal to male children, are—inflammation of the brain and its consequences, convulsions and hydrocephalus, inflammation of the lungs, stomach, bowels, &c., and fevers of all kinds,—some of the eruptive excepted. On the other hand, the diseases in which the deaths of female children preponderate are few in number,—the chief being hooping-cough, scarlet-fever, and consumption; whence he concludes, that the maladies most fatal to male children seem to be of the sthenic class,—to females, of the asthenic.

It would appear, that on the average, about one infant in twenty is still-born. The cause of this is a difficult inquiry; as well as that of the greater ratio—double—in cities than in the country; in some cities than in others; amongst male infants rather than females; in winter than in summer; and amongst the illegitimate rather than the legitimate. It is an interesting topic of investigation for the medical statistician. The following table, embracing the statistics of the Imperial lying-in Hospital of Vienna, which as before remarked, is the great receptacle for illegitimate conceptions, is interesting on account of the number of cases observed. It is given by Mr. Wilde,[2] of Dublin, who states, that it was collected and arranged with much care from the unpublished records of the hospital for the eight years ending Dec. 31, 1840, and exhibits the results of 25,906 deliveries, and 26,149 births.

NUMBER OF BIRTHS, 26,149.

Children,	Single births,		25,638	
	Twins, 248 times,		496, or 1 in	105·43
	Triplets, 5 "		15, or 1 in	5229·8
	Total births,		26,149	
Sex in 23,413 births,	Boys, 11,717; Girls, 11,696	Proportion of Males to 100 Females,		100·17
Sex of still-born children in 2201 births,	Boys, 48; Girls, 45; Total, 93	Proportion of Males to 100 Females,		106·66
Total still-born in 23,413 births,			939, or 1 in	24·92
Died before the ninth day in 23,222,			1482, or 1 in	15·66
Sexes in 95 of these,	Boys, 49; Girls, 46	Proportion of Males to 100 Females,		106·52
Abortions and premature deliveries in 25,705,			674, or 1 in	38·13

It will be observed, that the ratio of still-born is smaller than the average; yet it is much higher than in the whole of the Austrian dominions, in which the proportion, according to Mr. Wilde, was 1 in 30·62; and according to Knolz,[3] in 1843, in the province of Austria, 1 in 36·4. It is difficult, however, to believe, that Mr. Wilde's statistics can be accurate, when we observe the ratio in Linz stated to be 1 in 155·35 only![4] If all the statistical observations be esteemed accurate, they certainly exhibit a great and inexplicable difference in countries on all these topics. The official records of Belgium,[5] for ex-

[1] Amer. Journ. of the Med. Sciences, for Jan., 1846, p. 92.
[2] Op. cit., p. 223.
[3] Op. cit.
[4] Ibid., 225.
[5] Statistique de la Belgique.—Population, Mouvement de l'État Civil pendant l'Année 1844, p. vi., Bruxelles, Novemb., 1845.

ample, give the number of still-born legitimate males to that of still-born legitimate females as 1·39 to 1; whilst the ratio of still-born illegitimate males to females is only 1·14 to 1. The legitimate males born alive were to the females in the ratio of 1·05 to 1; the illegitimate of 1·04 to 1. The following was the proportion of single births, of the born alive, of the still born, and of twins to the whole number of births, including the still-born, in four successive years:—

	1841.	1842.	1843.	1844.
Single births,	1 in 1·02	1·02	1·02	1·02
Born alive,	1 in 1·04	1·04	1·04	1·04
Born dead,	1 in 25·97	25·67	24·09	23·76
Twins,	1 in 58·38	54·88	53·44	52·40

In 1841, there were 9 triple births (8 boys and 19 girls); in 1842, 16 (25 boys and 23 girls); in 1843, 10 (11 boys and 19 girls); and in 1844, 11 (20 boys and 13 girls). In 1842, there was one quadruple birth (all females); and in 1844, there were 2 (2 males and 6 females).

A recent German author, Dr. G. Thomas,[1] has estimated twin cases at 1 in 80; triplets at 1 in 6 to 7000; and quadruplets at 1 in 20 to 50,000 cases.

A statistical contribution to obstetrical physiology has been made by Professor J. Y. Simpson, of Edinburgh,[2] which is full of interest in this relation. From elaborate tables contained in Dr. Collins's Treatise on Midwifery, he deduces the following propositions. *First.* That the dangers and difficulties of parturition are greater to the mother in male than in female births. *Secondly.* That the dangers and accidents from parturition and its results are greater to the child in male than in female births: and *Thirdly.* That for the very marked difference between the difficulties and perils, both to the child and the mother, in male, from that which exists in female births, there is no other traceable cause in the mechanism of parturition, than the larger size of the head of the male child.

The records of the Dublin hospital showed, that there died during the process of parturition, "and probably as a consequence of the injuries to which they were subjected," 151 male children for every 100 female. There was thus an excess of 50 male deaths in every 250 children, or 20 in every 100;—referable, according to Dr. Simpson, to the greater size of the head of the male infant. "Further," he adds, "we may take it for granted, that, on a low computation, 1, in every 50 children born, dies during labour, about 1 in every 25 cases being a still birth. To be certain, however, not to overstep our limits, let us reckon only 1 in every 75 children to die during parturition, and 1 in every 5, or 20 per cent. of those that thus perish, to be formed by that excess of mortality of males over females, which we can trace to no other cause than the influence of the greater dimensions of the male head. In England and Wales about 500,000 births take place annually. By the above computation, more than 6500 of the offspring of these births die during labour, and one-fifth of that number are lost in consequence of the sex and size of the male child. In Great

[1] Die Physiologie des Menschen, S. 60, Leipz., 1853.

[2] Edinb. Med. and Surg. Journal, Oct., 1844.

Britain, therefore, the lives of 15,000 infants are annually lost in child-birth, from the operation of this agency."

Applying a similar mode of reasoning to account for the excess of male infants, who die within the first year after birth, Dr. Simpson concludes, that there perish annually in Great Britain, upwards of 5000 children within the first year after birth, whose death is referable to the influence of the sex, and greater size of the male head during labour.

e. *Superfœtation.*

It has been an oft-agitated question, whether, after an ovule has been impregnated and passed down into the cavity of the uterus, another ovule may not be fecundated; so that the products of two conceptions may undergo their respective developements in the uterus, and be delivered at an interval corresponding to that between the conceptions. Many physiologists have believed this to be possible, and have given it the name *superfœtation.* The case, cited from Sir Everard Home, of a young female, who died on the seventh or eighth day after conception, exhibits that the mouth of the womb is at an early period completely obstructed by a plug of impervious mucus—*mucus infranchissable* of M. Pouchet, and that the inner surface of the uterus is lined by an efflorescence of plastic matter, the nature of which will be described under the next head. When such a change has been effected, it would seem to be impossible for the male sperm to reach the ovary; and accordingly, the general belief is, that superfœtation is only practicable prior to these changes, and when there is a second vesicle ripe for impregnation. Of this kind of *superconception* or *superfecundation* it is probable, that twin and triplet cases are often, if not always, examples;—one ovule being impregnated at one copulation, and another at the next.[1] This seems to be common in animals. The dog-breeders have often remarked, that a bitch, after having been lined, will readily admit a dog of a very different kind to copulate with her; and different descriptions of puppies have been brought forth,—some resembling each of the fathers. Sir Everard Home[2] states, that a setter bitch was lined in the morning by a pointer. The bitch went out with the gamekeeper, who had with him a Russian setter of his own, which also lined her in the course of the afternoon. She had a litter of six puppies; two only of which were preserved. One of these bore an exact resemblance to the pointer; the other to the Russian setter,—the male influence being predominant in each.

Of this kind of superfœtation or double conception we have several instances on record, of which the following are amongst the most striking;—the male parent of the respective fœtuses having differed in colour. The first is the well-known case cited by Buffon[3] of a female at Charleston, South Carolina, who was delivered in 1714 of twins, within a very short time of each other. One of these was black; the other white. This circumstance led to an inquiry, when the woman confessed, that on a particular day, immediately after her husband had

[1] Art. Zwillinge, in Pierer's Anat. Physiol. Real. Wörterb., Band viii., Altenb., 1829.

[2] Lect. on Comp. Anat., iii. 302.

[3] Hist. Nat. de l'Homme, *Puberté.*

left his bed, a negro entered her room, and compelled her to gratify his wishes, under threats of murdering her. Several cases of women in the West India Islands having had, at one birth, a black and a white child, are recorded; and Dr. Moseley[1] gives the following case, which is very analogous to that described by Buffon. A negro woman brought forth two children at a birth, both of a size, one of which was a negro, the other a mulatto. On being interrogated, she said, that a white man belonging to the estate came to her hut one morning before she was up, and that she received his embraces soon after her black husband had quitted her. Sir Everard Home[2] likewise asserts, that a particular friend of his "knows a black woman, who has two children now alive, that are twins and were suckled together; one quite black, the other a mulatto. The woman herself does not hesitate in stating the circumstances: one morning just after her husband had left her, a soldier, for whom she had a partiality, came into her hut, and was connected with her, about three or four hours after leaving the embraces of her husband." One of the author's pupils, Dr. N. J. Huston, then of Harrisonburg, Virginia, also communicated to him the case of a female who was delivered, in March, 1827, of a negro child and a mulatto on the same night. Where negro slavery exists, such cases are sufficiently numerous:[3] two have been recorded recently.[4] So far, therefore, as regards the possibility of a second vesicle being fecundated, prior to the closure of the os uteri by the tenacious impenetrable mucus (*mucus infranchissable* of Pouchet), and the flocculent membranous secretion from the interior of the uterus, or by the decidua, no doubt, we think, can be entertained: but, except in cases of double uterus, it would seem to be impracticable afterwards; although cases have been adduced to show its possibility. Still, these may perhaps be explained under the supposition, that the uterine changes, above referred to, may not be as rapidly accomplished in some cases as in others; and, again, the period of gestation is not so rigidly fixed, but that children, begotten at the same time, or within a few days of each other, may still be born at a distance of some weeks. A case happened to the author in which nearly three weeks elapsed between the birth of twins, in whose cases the ova were probably fecundated either at the same copulation, or within a few hours of each other.

It may happen, too, that although two ova may be fecundated, both embryos may not undergo equal developement. One, indeed, may be arrested at an early stage, although still retaining the vital force. In such a case, the other will generally be found larger than common. A case of the kind occurred in the practice of Professor Hall, of the University of Maryland, and many such are on record. On the 4th of October, 1835, a lady was delivered of a female fœtus, 2 inches and 10 lines in length. This occurred about half-past eight in the morning; and at two o'clock on the following morning, she was delivered of a second child, which weighed 9½ pounds. The fœtus, whose develope-

[1] A Treatise on Tropical Diseases, p. 111.

[2] Op. cit.

[3] See, for an enumeration of cases, Beck's Medical Jurisprudence, 6th edit., i. 222; and Dr. Allen Thomson, in Cyclop. Anat. and Physiol., part xiii. p. 469, for Feb. 1838.

[4] Thomas B. Taylor, New Orleans Journal of Medicine, Nov. 1848; and R. Carter, Medical Examiner, Sept. 1849, p. 523.

ment was arrested, was seen by the author. When first extruded, it gave no evidences of decay, and in colour and general characters resembled the fœtus of an ordinary abortion.[1] Still, there are many cases recorded, in which the interval between the births of the children has been from 110 to 170 days, and neither of the children was in appearance premature; so that the possibility of a second conception, when the uterus already contains an ovum some months old, can scarcely, perhaps, be denied, however improbable it may seem; and, indeed, if the facts be admitted, the deduction seems to be irresistible.

f. *Pregnancy.*

When the fecundated ovum has been laid hold of by the fimbriated extremity of the Fallopian tube, and through this channel,—perhaps by the contraction of the tubes and the ciliary motions of its lining membrane,—has reached the cavity of the uterus, it forms a union with that viscus, to obtain the nutritive fluids which may be required for its developement, and to remain there during the whole period of *pregnancy* or *utero-gestation;*—a condition that will now require consideration.

Immediately after a fecundating copulation, and whilst the chief changes are transpiring in the ovary, certain modifications occur in the uterus. According to some, it dilates for the reception of the ovum. Bertrandi found this to be the case in extra-uterine pregnancy, and in females whom he opened at periods so near to conception, that the ovum was still floating in the uterus. Its substance appeared at the same time redder, softer, less compact, and more vascular than usual. In the case from Sir Everard Home,[2] to which allusion has been made more than once, the lining of the uterus was covered by a beautiful flocculent exudation about the seventh or eighth day after impregnation. The soft membrane, which forms in this way, is the *membrana caduca* seu *decidua externa*, first described by Hunter; the *epichorion* of Chaussier; *tunica exterior ovi, t. caduca, t. crassa membrana cribrosa, membrana ovi materna, membrana mucosa, decidua cellularis* et *spongiosa*, of others.

Fig. 440.

Decidua Uteri.

The dark shade, over and between the villi, is the decidua. The uterine vessels are seen extending into the decidua and forming loops there.

In a case, observed by Von Baer at a very early period, when the decidua was still in a pulpy state, the villi of the lining membrane of the uterus, which in the unimpregnated state are very short, were found to be remarkably elongated; and between the villi, and passing over them, was a substance not organized, but merely effused, and evidently the decidua at an extremely early age.[3] Others, as Weber[4] and Sharpey,[5]—and the view

[1] For similar cases, of which many are on record, see Dr. Samuel Jackson, formerly of Northumberland, Pa., now of Philadelphia, in American Journal of the Medical Sciences, May, 1838, p. 237, and May, 1839, p. 256; also, Dr. J. G. Porter, ibid., Aug., 1840, p. 307; Mr. Streeter, Lond. Lancet, Oct. 30, 1841; Dr. H. N. Loomis, Buffalo Medical Journal, June, 1845; and Dr. E. Horlbeck, Charleston Medical Journal and Review, Jan., 1848.

[2] Lect. on Comp. Anat., iii. 209, Lond., 1823.

[3] Op. citat.; and Wagner's Physiology, by Willis, p. 184, Lond., 1841.

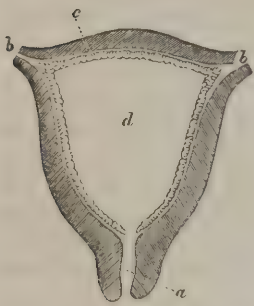
[4] Hildebrandt, Handbuch der Anatomie, iv. 486 and 515, Braunschweig, 1832.

[5] Müller's Elements of Physiology, by Baly, note at p. 1574, Lond., 1838.

has been embraced by many eminent observers,—have maintained, that the decidua is composed of the mucous membrane itself, which has undergone a considerable change in its character, and in the secretion from its follicles.

The arrangement of this membrane has given rise to much discussion. The opinions of most of the anatomists of the present day are in favour of one of two views. It is maintained by some, that one of the first effects of conception is to cause the secretion of a quantity of a sero-albuminous substance from the inner surface of the uterus; so that the organ becomes filled with it. At first, when the ovum arrives in it, it falls into the midst of this secretion, gradually absorbing a part for its nutrition by its outer surface. The remainder is organized into a double membrane, one corresponding to the uterus, the other adhering to the ovum. This sero-albuminous substance has been assimilated both to the white with which the eggs of birds become invested in passing through the oviduct; and to the viscid substance that envelopes the membranous ova of certain reptiles. It is conceived, by some, to plug up both the orifices of the Fallopian tubes, and that of the uterus; and, according to Krummacher[1] and Dutrochet,[2] it has been seen extending into the tubes; whilst the remains of that which plugged up the os uteri has been recognised in the shape of a nipple on the top of the aborted ovum. To this substance M. Breschet[3] has given the name *Hydropérione*. By others, it has been held, that a decidua is formed prior to the arrival of the ovum, lines the whole of the cavity and is devoid of apertures; so that when the ovum passes along the tube and attains the cornu of the uterus, it pushes the decidua before it;—the part so pushed forwards constituting the *tunica decidua reflexa* or *ovuline*, and enveloping the whole of the ovum except at the part where the decidua leaves the uterus to be reflected over it. This

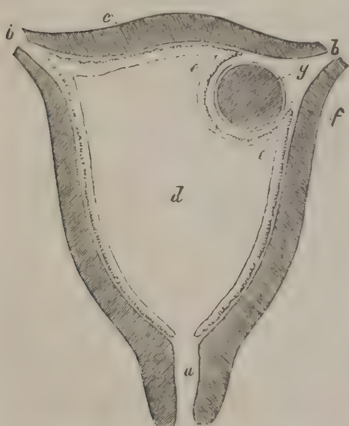
Fig. 441.



Section of the Uterus about eight days after Impregnation.

a. Cervix. *b, b.* Orifices of Fallopian tubes. *c.* Decidua vera. *d.* Cavity of uterus.

Fig. 442.



Section of the Uterus when the Ovum is entering its Cavity.

Ovum, *f*, surrounded by its chorion *g*. *a.* Cervix. *b, b.* Fallopian tubes. *c.* Decidua vera. *d.* Cavity of the uterus. *e.* Decidua reflexa.

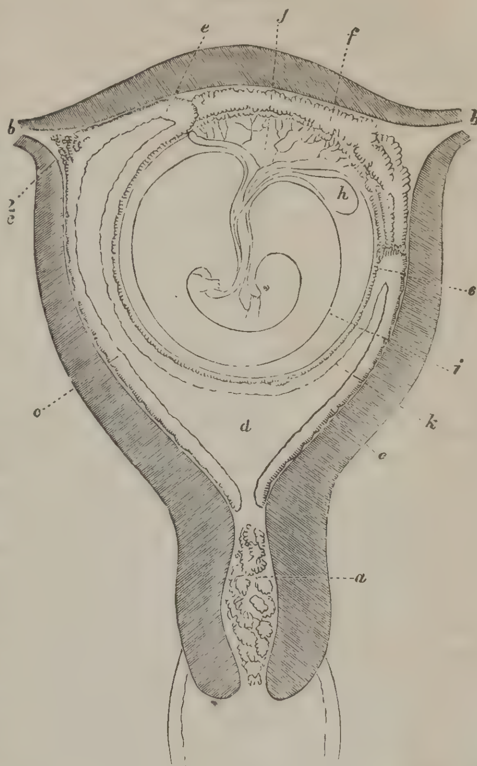
[1] Diss. Sistens Observationes quasd. Anatom. circa Velamenta Ovi humani, Duisb., 1790.

[2] Mém. de la Société Médicale d'Émulation, viii. p. i. 1817.

[3] Études Anatomiques, Physiologiques, et Pathologiques de l'Œuf dans l'Espèce Humaine, &c., Paris, 1832.

is the seat of the future *placenta*. Such is the view of MM. Velpeau,[1] Wagner,[2] Kirkes and Paget[3] and others. An objection to it, however, is the difficulty of so small a body pushing the decidua before it; and a still stronger is the assertion of Professor Sharpey, that the structure of the decidua and of the decidua reflexa is different, a fact long since mentioned by Dr. William Hunter,[4] who describes the decidua reflexa as a membrane of considerable thickness, and of a yellower colour than the decidua vera.[5] Hence, it has been thought more probable, that the latter is almost entirely a new production, the growth of which is simultaneous with the enlargement of the ovum; and that the decidua vera has no more share in its formation than by supplying, through its vessels, the necessary materials. At the point of supposed reflection of the decidua reflexa, there is a thick stratum of a substance precisely similar to the decidua reflexa, which attaches the ovum to the side of the uterus, and blends intimately on the outer side of the reflex fold with the decidua vera. This is termed *decidua serotina*, from its appearing to have been formed at a later period. It is represented in Fig. 443.

Fig. 443.



Section of the Uterus with the Ovum somewhat advanced.

a. Muco-gelatinous substance, blocking up os uteri. *b*, *b*. Fallopian tubes. *c*, *c*. Decidua vera prolonged, at *c* 2, into Fallopian tube. *d*. Cavity of uterus, almost completely occupied by ovum (compare with Fig. 442). *e*, *e*. Angles at which decidua vera is reflected. *f*. Decidua serotina. *g*. Allantois. *h*. Umbilical vesicle. *i*. Amnion. *k*. Chorion, lined with outer fold of serous tunic.

The view of Dr. Burns[6] differs from this in supposing that the decidua consists of two layers, the innermost of which has no aperture, so that the ovum, on attaining the cornu of the uterus, pushes it for-

[1] Traité Élémentaire de l'Art des Accouchemens, i. 231, Paris, 1829, or Prof. Meigs's translation, 2d edit., p. 246, Philadelphia, 1838; also, Embryologie ou Ovologie Humaine, Paris, 1833.

[2] Op. citat., p. 188.

[3] Manual of Physiology, Amer. edit., p. 481, Philad., 1849: see, on this subject, Baly and Kirkes, Recent Advances in the Physiology of Motion, the Senses, Generation, and Developement, p. 90, Lond., 1848.

[4] Anatomical Description of the Gravid Uterus and its Contents, Lond., 1799.

[5] Müller, loc. cit.

[6] Principles of Midwifery, 3d edit., p. 147, Lond., 1814.

wards, and it forms the *decidua protrusa* or *decidua reflexa ;* and a somewhat modified view of the same kind appears to be entertained by Prof. Weber. Impregnation, according to M. Velpeau, occasions a specific excitation in the uterus, promptly followed by an exhalation of coagulable matter. This concretes, and is soon transformed into a kind of cyst or ampulla, filled with a transparent or slightly rose-coloured fluid. This species of cyst is in contact with the whole surface of the uterine cavity, and sometimes extends into the commencement of the tubes, and most frequently into the upper part of the cervix uteri, in the form of solid concrete cords; but is never, he says, perforated naturally, as Hunter, Bojanus, Lee, and others have maintained. The decidua uteri, according to M. Velpeau, retains a pretty considerable thickness, especially around the placenta, until the end of gestation: the decidua reflexa, on the contrary, becomes insensibly thinner and thinner, so that at the full period it is at times of extreme tenuity. Towards the third or fourth month—a little sooner or later—they touch and press upon each other, and remain in a more or less perfect state of contiguity, until the expulsion of the secundines; but M. Velpeau asserts they are never confounded; and such appears to be the view of Bischoff.[1] The decidua—the true as well as the reflected—is esteemed by M. Velpeau a simple concretion—a layer without regular texture—the product of an excretion from the lining membrane of the uterus: on this account, he terms it, "*anhistous membrane*," (from αν, privative, and ἱστος, "a web") or "membrane without texture." There has, indeed, been a striking dissatisfaction with the name "decidua." Besides the appellatives already given, M. Dutrochet has proposed to call it *épione*, M. Breschet, *périone*, Seiler, *membrana uteri interna evoluta*, and Burdach, *nidamentum*.

A difficulty exists in understanding how the decidua is formed continuously over the orifice of the Fallopian tubes, and the upper surface of the cervix uteri. A new production must evidently take place there. By some, however, it is not presumed to exist in the latter situation; but a plug of muco-gelatinous matter is found there, as in Fig. 443, *a*.

The use of the decidua is, in M. Velpeau's opinion, to retain the fecundated ovum to a given point of the uterine cavity; and if his views of its arrangement were correct, the suggestion would be good. In favour of it a good deal might be said. If there were apertures in the decidua corresponding to the Fallopian tubes, it would seem, that the ovum ought more frequently to fall into the sero-albuminous matter about the cervix uteri, and attachment of the placenta over the os uteri ought, perhaps, to occur more frequently than it is known to do. When placenta prævia does exist, it is owing, in the opinion of Dr. Doherty,[2] to the decidua being imperfect, or to the ovum descending into the uterine cavity before that membrane has acquired sufficient consistence and tenacity to resist its weight: the consequence is, that the ovum must make its way to the cervix uteri and give occasion to implantation of the placenta there. Under M. Velpeau's doctrine, the attachment of the placenta ought generally to be near the cornu

[1] Wagner, op. citat. p. 190 (note).
[2] The Dublin Journal of Medical Science, July, 1845, p. 333.

of the uterus, which is, in fact, the case. Of 34 females, who died in a state of pregnancy at the *Hôpital de Perfectionnement*, an examination of the parts exhibited, that in twenty the centre of the placenta corresponded to the orifice of the Fallopian tube; in three, it was anterior to it; in two, posterior; in three, beneath; and in six, near the fundus of the uterus. It is not so easy to subscribe to his assertions regarding the "anorganic" nature of the decidua. Many excellent observers have affirmed, not only that this membrane exists between the placenta and the uterus, which M. Velpeau's view, of course, renders impossible, but that numerous vessels pass between it, the uterus, and the placenta. We know, too, that the safest and most effectual mode of inducing premature labour is to detach the decidua from the cervix uteri; or, in other words, to break up the vessels that form the medium of communication between it and the lining membrane of the uterus. It may be said, indeed, that the mere separation of the "anorganic pellicle"—as M. Velpeau designates it—is a source of irritation, and may excite the uterus to the expulsion of its contents, and this is possible; but he affirms, that no tissue attaches the decidua to the uterus; and that it adheres to the inner surface of the organ merely in the manner of an excreted membraniform shell (*plaque*). The views of MM. Lepelletier[1] and M. Raspail[2] coincide with those of M. Velpeau as to the decidua being an excretion; but those of M. Raspail are modified by his peculiar opinions. He maintains, that the surfaces of an organ—whether external or internal—having once fulfilled their appropriate functions, become detached and give place to the layer beneath them; and we have before remarked, that he considers the secretions of the mucous and serous membranes to be constituted of the *detritus* of those membranes. Now, that which happens to the intestinal canal and bladder must likewise happen, he affirms, to the uterus; and as, at the period of gestation, it surpasses in developement, elaboration, and vitality, every other living organ, it ought necessarily to cast off its layers, in proportion as they have executed the work of elaboration. These *deciduous* layers constitute the *decidua*, on which, he says, traces of a former adhesion to the parietes of the uterus, and of the three apertures into the organ, may be met with.

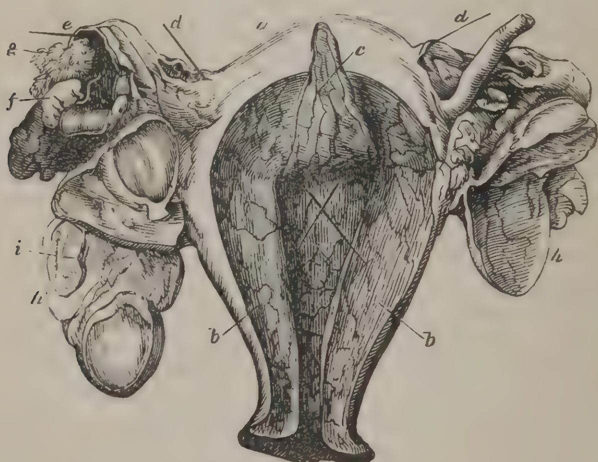
But the very existence of a decidua reflexa has been denied. It is so by Jörg,[3] Samuel,[4] and by Dr. Granville, who affirms, that it is now scarcely admitted by one in ten of the anatomists of the European continent. He refers to a specimen of an impregnated uterus in the Museum of the Royal College of Surgeons of London, which has distinctly a round ovum, suspended naturally within the decidua, as a globe may be supposed to hang from some point of the interior of an oblong sac; and to two specimens, in the collection of Sir Charles Clarke, exhibiting an ovum, which had already penetrated about an inch into the cavity of the uterine decidua; but neither in these, nor in the specimen at the Royal College, is any part of the uterine decidua

[1] Physiologie Médicale et Philosophique, iv. 339, Paris, 1833.
[2] Chimie Organique, p. 270, Paris, 1833.
[3] Das Gebärorgan des Menschen, u. s. w., Leipz., 1808.
[4] De Ovorum Mammal. Velament. Wirceb., 1816; and art. Ei, in Encyclop. Wörterb. der Med. Wissensch., x. 107, Berlin, 1834.

pushed forward. The ovum appears to have its natural covering; and, in the College specimen, there is a large space between it and the deciduous lining of the uterus. Dr. Granville regards the decidua reflexa as the external membrane of the ovum, to which Professor Boër, of Königsberg, gave the name "cortical membrane," and which he terms *cortex ovi*.[1] It has received various names. By Albinus, it was termed *involucrum membranaceum;* by Hoboken, *membrana retiformis chorii;* by Roederer, *membrana filamentosa;* by Blumenbach, *membrana adventitia;* and by Osiander, *membrana crassa.* To this membrane—and to the decidua uteri, as connected with the placenta—we shall have to refer hereafter.

The decidua manifestly does not belong to the ovum; for it not only exists prior to the descent of the ovum into the uterus, but is even formed, according to M. Breschet,[2] in all cases of extra-uterine pregnancy. (See Fig. 444.) Chaussier saw it in several cases of tubal gestation. It was present in a case of abdominal pregnancy, cited by Lallemant; and, according to M. Adelon,[3] Evrat affirms, that one is secreted after every time of sexual intercourse,—which is apocryphal! It would appear, however, to be formed at each menstrual period, and, according to M. Pouchet,[4] is thrown off from the tenth to the fifteenth day afterwards. He is of opinion, that the decidua is produced simply

Fig. 444.



Extra-Uterine Pregnancy.

a. Uterus, its cavities laid open. *b.* Its parietes thickened, as in natural pregnancy. *c.* A portion of decidua separated from its inner surface. *d.* Bristles to show the direction of the Fallopian tubes. *e.* Right Fallopian tube distended into a sac which has burst, containing the extra-uterine ovum. *f.* Fœtus. *g.* Chorion. *h.* Ovaries; in the right one is a well-marked corpus luteum, *i.*

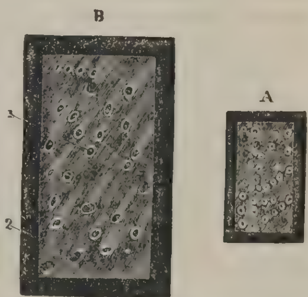
by the irritation, which succeeds to menstruation, and that it is nothing more than a pseudo-membrane "secreted between the surface of the

[1] Graphic Illustrations of Abortion, &c., p. v., Lond., 1834.
[2] Repert. Général d'Anatomie, p. 165, pour 1828.
[3] Physiologie de l'Homme, 2de édit., iv. 110, Paris, 1829.
[4] Théorie Positive de l'Ovulation Spontanée, p. 254 and p. 463, Paris, 1847.

mucous membrane and the epithelium," and taking the latter with it, is afterwards discharged;—an arrangement which is not very intelligible. Dr. Robert Lee[1] affirms, that it is not formed within the uterus in all cases of extra-uterine gestation; and in ten cases detailed by him, and in one cited from M. Chaussier, it was seen distinctly surrounding the ovum in the Fallopian tube.[?]

The views of Professor Goodsir[2] on the morphology of the decidua merit great attention. By the observations of Weber and Sharpey, it had been shown, that it is not a structure of new formation; but that when impregnation has taken place, the mucous membrane of the uterus swells and becomes lax, its tubular follicles—*glandulæ utriculares*—increase in size, secrete a granular matter, and are lined with epithelium; and its capillaries enlarge proportionally. M. Coste[3] restricts the uterine changes to these. "The only modifications"—he remarks—"of which the uterus becomes the seat consist in the turgescence or erethism of its tissue, and more especially in a considerable thickening of the mucous membrane;—a thickening which results especially from congestion of the bloodvessels, and an extreme developement of the glands, that enter into its composition, and, in certain subjects, plait them into more or less numerous convolutions." "In the normal state"—he affirms—"neither the opening of the cervix uteri nor that of the Fallopian tubes is closed by membrane." They are always free, permeable, and consequently permit the ovum to pass into the cavity of the uterus, and the folds of the mucous membrane, by coming in contact, are sufficient to arrest it. Mr. Goodsir has remarked, however, that the interfollicular spaces, in which the network of capillaries lies, are occupied by a texture consisting entirely of nucleated particles; "this is a tissue represented by Baer and Wagner, and described by them as surrounding what they supposed to be uterine papillæ (really the enlarged follicles), and considered by them as decidua." The increased thickness of the mucous membrane appears as much due to the developement of this interfollicular substance, as to the enlargement of the follicles. About the time at which the ovum reaches the uterus, the developed mucous membrane or decidua begins to secrete; the os uteri becomes plugged up by the secretion, which there assumes the form of elongated epithelial cells; the cavity of the uterus becomes filled with a fluid secretion, the *hydropérione* of M. Breschet; and in the immediate neighbourhood of the ovum, it consists of cells of a spherical form. Thus, the decidua, according to him, consists of two distinct elements;—the mucous membrane of the uterus

Fig. 445.



Two thin segments of Human Decidua, after recent impregnation, viewed on a dark ground; they show the openings on the surface of the membrane.

A is magnified 6 diameters and B twelve diameters. At 1, the lining of epithelium is seen within the orifices; at 2 it has escaped.

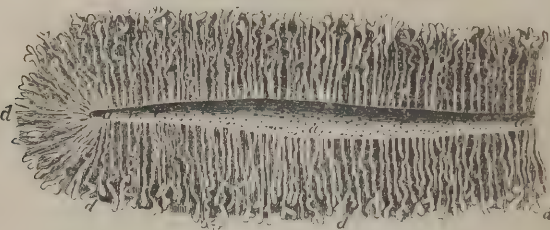
[1] Lond. Med. Gazette, June 5, 1840.

[2] Anatomical and Pathological Observations, Edinb., 1845.

[3] Histoire Générale et Particulière du Développement des Corps Organisés, p. 220, Paris, 1847.

thickened—as remarked by Dr. Sharpey, and confirmed by Bischoff,[1] Courtz,[2] and others—by a peculiar developement, and by non-vascular

Fig. 446.



Section of the lining membrane of a human uterus at the period of commencing pregnancy, showing the arrangement and other peculiarities of the glands *d*, *d*, *d*, with their orifices, *a*, *a*, *a*, on the internal surface of the organ. Twice the natural size.

cellular substance, the product of the uterine follicles; the former constitutes, at a later period, the greater part of the decidua vera; the latter the decidua reflexa. This view of the constitution of the decidua —in Mr. Goodsir's opinion—clears up the doubts which were entertained regarding the arrangement of these membranes at the os uteri and the entrances of the Fallopian tubes. The orifices will be opened or closed, according as the cellular secretion is more or less plentiful, "or in a state of more or less vigorous developement." It removes also —he conceives—the difficulty of explaining how the decidua covers the ovum—a difficulty, which cannot be reconciled with the views of Dr. Sharpey, who supposes a deposition of lymph—the old view of the constitution of the decidua. When the ovum enters the cavity of the uterus, the cellular decidua surrounds it, and becomes the decidua reflexa by a continuance of the same action by which it had been increasing in quantity prior to the arrival of the ovum. The cellular decidua grows around the ovum, by the formation of new cells, the product of those in whose vicinity the ovum happens to be situate. At this stage of its growth, the ovum with its external membrane, the chorion, which is covered by the tufts whose structure and functions are described elsewhere, is embedded in a substance that consists wholly of active nucleated cells. The absorbing cells of the tufts are constantly taking up either the matter resulting from the solution of the cells of the cellular decidua, or the fluid contained in those cells,—in either case from matter supplied by the vessels of the uterus, but selected and prepared by the cells of its lining membrane, now become the decidua.[3]

Mr. Goodsir's view harmonizes more than any of those mentioned with the mode in which new structures would seem to be formed elsewhere. M. Coste[4] has, however, thrown the greatest light on this subject. When the ovum enters the uterus, it becomes partially imbedded in the substance of the decidua, which is, as yet, quite soft; and experiences an increase of nutrition at the part with which the ovum comes in contact; growing up around it until it has completely enveloped the

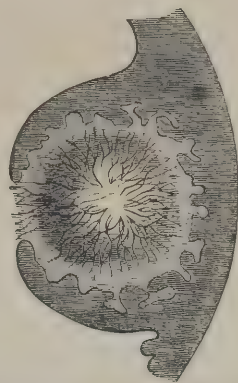
[1] Müller's Archiv., H. ii., 1846, p. 111.
[2] Archives d'Anat. général et de Physiol., Sept., 1846; cited by Dr. Kirkes in Ranking's Abstract, vol. iv.
[3] British and Foreign Med. Rev., Oct., 1845, p. 303.
[4] Comptes Rendus, Mai 24, 1847.

ovum; and in this way the decidua reflexa is, in reality, a part of the decidua uteri. As the ovum becomes developed, the cavity between the

Fig. 447.

First stage of the formation of the Decidua reflexa around the Ovum.

Fig. 448.



More advanced stage of Decidua reflexa.

decidua vera and the outer surface of the decidua reflexa gradually diminishes, and by the end of the third month the two portions come in contact, and are thereafter scarcely or not at all distinguishable.[1]

In the summer of 1854, the author had the advantage of examining the preparations of M. Coste, and of being favoured with his explanation of them. They certainly established the view taught by that distinguished embryologist of the mode of formation of the decidua reflexa.

When the ovum attains the interior of the uterus, which it probably does within the first ten or twelve days after conception, it forms, in a short space of time, a connexion with the uterus by means of the placenta, in the mode to be mentioned hereafter. During the developement of the embryo, it is requisite that the uterus should be correspondently enlarged, in order to afford room for it, as well as to supply it with its proper nutriment. These changes in the uterine system will engage us exclusively at present. In the first two months, the augmentation in size is not great, and chiefly occurs in the pelvis; but, in the fourth, the increase is more rapid. The uterus is too large to be contained in the pelvis, and consequently rises into the hypogastrium. During the next four months, it increases in every direction, occupying a larger and larger space in the cavity of the abdomen, and crowding the viscera into the flanks and the iliac regions. At the termination of the eighth month, it almost fills the hypogastric and umbilical regions; and its fundus approaches the epigastric region. After this, the fundus is depressed and approaches the umbilicus, leaving a flatness above, which has given rise to the old French proverb;—*En ventre plat enfant il y a.* During the first five months of utero-gestation, the womb experiences but little change, maintaining a conoidal shape. After this, however, the neck diminishes in length, and is ultimately almost entirely effaced. The organ has now a decidedly ovoid shape; and its

[1] See Béraud, Manuel de Physiologie de l'Homme, &c., revu par M. Ch. Robin, p. 449, Paris, 1853.

bulk, according to Haller and Levret, is eleven and a half times greater than in the unimpregnated state. Its length, at the full period, has been estimated at about a foot; its transverse diameter at nine inches; its circumference on a level with the Fallopian tubes, at twenty-six inches; and, at the uterine portion of the cervix uteri, thirteen inches. Its weight, which, prior to impregnation, was from fourteen to eighteen drachms, is, at this time, from a pound and a half to two pounds.

Whilst the uterus is undergoing expansion, the size and situation of the parts attached to it also experience modification. The broad ligaments are unfolded; the ovaries and Fallopian tubes are raised a little, but are subsequently applied against the sides of the uterus. The vagina is elongated. The round ligaments yield to the elevation of the organ as far as their length will permit; but, ultimately, they draw the uterus forward, so that the great vessels of the abdomen are not injuriously compressed. The parietes of the abdomen are so much distended that the cuticle yields; hence, an appearance of cicatrices always exists on the abdomen of one who has borne children; and occasionally, the fasciculi of the abdominal muscles separate so as to give rise to ventral hernia.

The changes, produced in the uterus, are not limited to simple dilatation of its tissue. Its condition experiences various alterations, dependent upon the new mode of nutrition it has assumed. The whole organ undergoes not only extension but inspissation of its parietes. In its unimpregnated state, it is about four lines thick; in the third month of utero-gestation, five. Its arteries, as well as veins, enlarge, and the latter form large dilatations at the inner surface. These have been called *uterine sinuses.* Its lymphatics are greatly increased in size; and its proper tissue, from being hard, whitish, and incontractile, becomes red, soft, spongy, and capable of energetic contraction. It has been the general opinion, that the nerves exhibit a corresponding increase during the gravid state, but the dissections of Mr. Beck,[1] which have received favour from Dr. Sharpey,[2] prove, that they do not alter in their thickness, "at least, that no alteration occurs before they enter the tissue of the uterus." The representations of the gravid uterus, and of the unimpregnated uterus of one who had borne children, which are given in Mr. Beck's communication, show the nervous fibrils to be the same in both cases; and no difference was observed on the dissection of a virgin uterus between its nerves and those referred to. M. Jobert,[3] too, observed no difference in the nerves in the impregnated and the unimpregnated state; and M. Rendu[4] considers, that the knots observable in the course of the nerves during pregnancy are not formed of nervous substance, but of the fibro-cellular tissue that sustains and protects them.

A difference of sentiment has existed with regard to the nature of the new tissue of the uterus; some comparing it to the middle coat of

[1] Philosophical Transactions, Part 2 for 1846.

[2] Quain's Human Anatomy, by Quain and Sharpey, Amer. edit., by Leidy, ii. 356, Philad., 1849.

[3] Comptes Rendus, Paris, 1841.

[4] Thèse de Paris, 1842; cited by Ollivier, Art. Utérus (Anatomie) in Dict. de Médecine, xxx. 194, Paris, 1846.

arteries; others describing it as partly areolar and partly muscular; but an immense majority esteeming it muscular. The respectable name of Blumenbach[1] is in the minority. The facts in favour of its muscularity are, indeed, overwhelming. It is clearly muscular in the mammiferous animal. Thus, in the rabbit, its muscularity, according to Dr. Blundell,[2] is far more conspicuous than that of the intestines; the fibres can be seen coarse and large, and their motion may be observed, if they be examined immediately after the rabbit is killed. The same acute physiologist remarks, that, when developed by pregnancy, its muscularity is so clear, that if you take a portion of it, and show it to any anatomist, asking him what its nature is, he will unhesitatingly reply—it is muscular. This experiment, he says, he once made himself. He took a piece of the impregnated uterus, showed it to Mr. Green and Mr. Key—"excellent judges on this point,"—and, without mentioning the womb, asked them to tell him what was the structure; when they immediately declared it muscular. A similar experiment had previously been tried upon Mr. Else, who had made up his mind as to the non-muscularity of the organ. A small portion was taken to him for his opinion of its precise nature. It was from the uterus at an advanced period of utero-gestation. After carefully examining it, he gave for answer, that in his opinion it was muscular; but as it was detached from its natural locality, he could not say to what part of the body it belonged. When told, however, that it was a piece of the uterus, he examined it again, and *then* said that it could not be muscle, for there were no muscular fibres in the uterus.[3] The arrangement of the fibres is not clearly demonstrated. Generally, perhaps, they are described as running externally, in a longitudinal direction, from the fundus to the neck: beneath this plane is another with circular fibres; but within this the fibres are interlaced in inextricable confusion. Some anatomists, however, enumerate as many as seven superposed planes. The fibres are of much lighter colour than those of ordinary muscles; resemble more those of the bladder and intestines, and are collected in very flat and loose fasciculi. Under the microscope, they are manifestly of the nonstriated kind; but, towards the end of utero-gestation, fibres, of a faintly striated character, resembling those of the heart—it is affirmed—have been seen. The developement of this structure would not seem to be limited to the pregnant condition. It appears to occur whenever the uterus is increased in size, as has been remarked by Dr. Horner[4] and by Lobstein.[5] The muscular layers are thickest at the fundus uteri. At the cervix, they are extremely small and indistinct.

After the ovum has attained the interior of the uterus, and entered the flocculent decidua, it becomes connected, in process of time, with the uterus, by means of a body to be described hereafter, called *placenta*, which is attached to the uterus, and communicates with the

[1] Instit. Physiol., § 547.
[2] Principles and Practice of Obstetricy, Amer. edit., p. 67, Washington, 1834.
[3] D. Davis, Principles and Practice of Obstetric Medicine, ii. 850, Lond., 1836.
[4] Lessons in Practical Anatomy, p. 304, Philad., 1836.
[5] Fragment d'Anatomie Physiologique sur l'Organisation de la Matrice dans l'Espèce Humaine, Paris, 1803.

fœtus by a vascular cord that enters its umbilicus. The seat of the attachment of the placenta to the uterus—we have seen—is not always the same. Frequently, it is near one of the cornua; but occasionally it is implanted over the os uteri. The diversity of position has given occasion to difference of sentiment regarding the causes that influence it. By some, it has been presumed, that, in whatever part of the uterus the ovum lodges when it quits the Fallopian tube, there an adhesion is formed. By others, it has been said, that as the ovum pushes the decidua over the mouth of the Fallopian tube before it, the attachment of the placenta must be near the orifice of the tube. Such would appear to be the fact in the majority of cases, but we see so many irregularities in this respect, as to preclude us from assigning any very satisfactory reason for it.

g. *Signs of Pregnancy.*

Along with the changes that supervene in the generative apparatus during pregnancy, the whole system commonly sympathizes more or less in the altered condition. Some females, however, pass through the whole course of gestation with but slight or no disturbance of the ordinary functions; whilst with others, it is a period of incessant suffering. One of the earliest and most common signs is suppression of the catamenial discharge; but, of itself, this cannot be relied on, as it may result from disease. Soon after impregnation, the digestive and cerebral functions exhibit more or less modification. The female is affected with nausea and vomiting, especially in the morning after rising; the appetite is most fastidious—substances, that previously excited loathing being at times desired or *longed* for with the greatest avidity; whilst, on the contrary, cherished articles of diet cannot be regarded without disgust. The sleep is apt to be disturbed; the temper unusually irritable, even in those possessed of signal equanimity on other occasions. The mammæ enlarge, and become knotty, and sometimes lancinating pains are felt in them; and a secretion of a whitish serum can often be pressed out. The areola round the nipple becomes of a darker colour in the first pregnancy than it is in the virgin state; and it is darker during each successive pregnancy than when the female is not pregnant. There is, also, a puffy turgescence, not alone of the nipple, but of the whole of the surrounding disk, with a developement of the small follicles around the nipple. These appearances constitute one of the best single proofs of the existence of pregnancy; but it is obvious, that for accurate discrimination it is necessary to be aware of the hue in each particular case in the unfecundated state; and, moreover, instances are on record of a well-marked areola occurring in persons who are not pregnant, as well as of an entire absence of areola in those who are. Dr. Guy remarks, that Dr. J. Reid showed him a case of enlarged mammæ, with distinct areolæ and mucous follicles, in a female who had never been, and was not at the time, pregnant.[1] Dr. Simpson[2] presented before the Edinburgh Obstetrical Society a woman, seven months gone with child, whose breasts gave

[1] Lond. Lancet, Dec. 22, 1838.
[2] Monthly Journal of Medical Science, July, 1848, p. 244.

no indication whatever of her pregnant state. There was no appearance on either of enlarged follicles, and the areola was scarcely darker than the surrounding skin; yet that she was pregnant was shown by the fact, that the pulsations of the fœtal heart were distinctly heard. Dr. Simpson contrasted this case with that of a lady, who had never been pregnant, but who was suffering from great uterine irritation. In her, the areola was turgid, and of a dark brown colour; and the papillæ were numerous and much enlarged.

The author has had numerous opportunities for appreciating the insufficiency of these evidences taken singly.

It has been affirmed by Dr. Kluge, of Berlin, M. Jacquemin, of Paris, and Dr. D'Outrepont,[1] that a bluish tint of the vagina, extending from the os externum to the os uteri, is a sure test of pregnancy. According to Kluge, this discoloration commences in the fourth week of utero-gestation, increases until the time of delivery, and ceases with the lochia. M. Jacquemin, on examining the genitals of prostitutes, in compliance with the police regulations of Paris, observed the same peculiarity of colour in the same situation in those that were pregnant: he describes it as a violet or lees of wine colour, and so distinct as never to deceive him, being sufficient of itself, and independently of other signs of pregnancy, to determine the existence of that state. M. Parent-Duchatelet[2] affirms that he was present when M. Jacquemin's accuracy in this matter was successfully put to the test: in the investigation, he examined no less than 4500 prostitutes. Dr. D'Outrepont has not only met with this appearance uniformly in the human subject, but in different animals, examined in every period of pregnancy, and which he destroyed, to ascertain the existence or non-existence of gestation; and similar testimony has been given by Dr. Albert.[3] Dr. Montgomery,[4] however,—from limited observation it is true,—found, that whilst in some cases the bluish colour was very obvious, in others it was so slight as to be scarcely, or not at all, perceptible.

There is nothing more probable, than that the capillary circulation of the mucous coat of the vagina may be modified along with that of the interior of the uterus during pregnancy, so as to give occasion to the change of colour mentioned by those eminent observers; but it may be doubted whether the test can often be available, especially in private practice.

It is the general opinion, that the blood of pregnancy always presents the buffy coat and other characters of inflammation; and this has even been reckoned as one of the rational signs of pregnancy. Dr. Montgomery[5] ascribes the very general belief in this, as an established fact, to the circumstance, that pregnant women are seldom bled except when labouring under some form of inflammatory disease; and he affirms, that he has often found the blood of the pregnant female with-

[1] Zeitschrift für Geburtsk., xiv. 3; cited in Philad. Medical Examiner, Feb. 24, 1844, p. 46.

[2] De la Prostitution dans la Ville de Paris, i. 217, 218, Paris, 1837.

[3] Zeitschrift für Geburtskunde, xxiii. 449, cited in British and Foreign Medico-Chirurgical Review, July, 1848, p. 267.

[4] Op. citat., p. vi., Lond., 1837.

[5] Art. Pregnancy and Delivery, Signs of, in Cyclop. of Prac. Med., Amer. edit., by the author, iii. 679, Philad., 1845.

out these characters. Hematological researches, however, show that the blood in pregnancy is materially altered. Simon[1] found that of a woman in the fifth month with a slight buffy coat, but in other respects it did not differ physically from normal blood; and MM. Becquerel and Rodier[2] analyzed that of nine pregnant women,—one at the fourth month, five at the fifth month, one at five months and a half, one at six months, and one at seven months. From these they concluded, that although pregnancy, when not far advanced, and when it has not yet exerted any sensible influence on the constitution, may not occasion any obvious alteration of the blood, it becomes sensibly changed as pregnancy advances;—the main modifications being,—that the density both of the defibrinated blood and the serum is diminished; the water, fibrin, and phosphuretted fat are increased; whilst the corpuscles and albumen are diminished. For these and other reasons, it has been maintained by M. Cazeaux[3] that the cause of many of the functional derangements in pregnancy, which are attributed to polyæmia or plethora, is really owing to hydræmia or a condition of the blood like that of chlorosis.

Some years ago,[4] it was affirmed, that a German physician, Dr. Pallender, during a practice of eighteen years, had observed a peculiar smell of the vaginal mucus to be a constant and unerring sign of pregnancy. The smell is musty, something resembling that of sperm or of liquor amnii; and after a vaginal examination, he says, cannot be mistaken for any other odour. In a great many cases of pregnancy, in the first, second, and third months, when the condition of the patient was doubtful owing to the early period, he never, in a single instance, failed to discover the true state of the case by means of this sign. According to his latest observations, the odour is perceptible as early as the eighth day of utero-gestation. The author knows nothing of this sign.

Attention has been paid to the condition of the urine during utero-gestation; but although a difference has appeared to exist between it and that of an unimpregnated female, it has not generally been esteemed distinctive. M. Donné,[5] indeed, affirms, that in pregnancy it contains less uric acid and phosphate of lime than in the natural state, —a difference explicable if we consider the elements that are necessary for the formation of the organs of the fœtus. The crystallization of the salts of the urine is so remarkably modified, that by simple inspection, without examining the female, he recognized in more than thirty cases the state of pregnancy at different periods. The observations of M. Donné in regard to the diminution in the quantity of earthy phosphates in the urine are confirmed by Lehmann and Lubansky. It is a curious circumstance, connected with this matter, that Rokitansky[6] noticed a deposition of bony matter—*osteophyte*—on the inner surface

[1] Animal Chemistry, Syd. Soc. edit., p. 335, Lond., 1845.

[2] Gazette Médicale de Paris, Nov. 23 and 30; and Déc. 7, 14, and 21, 1844.

[3] Archives Générales de Médecine, Mars, 1850, p. 356.

[4] Northern Journ. of Med., Nov., 1845; cited from Med. Corresp. Rhein und Westfal Aerzte, 1845, Bd. iv. H. i.

[5] Gazette Médicale de Paris, 29 Mai, 1841.

[6] Pathologische Anatomie, ii. 237; or Sydenham Society's edit. of the English translation, iii. 208, Lond., 1850; or Amer. edit., Philad., 1855.

of the parietes of the skull of pregnant women, who had died suddenly after the third month of utero-gestation; as well of those who had died of different diseases, sooner or later after delivery; this he had witnessed so frequently, that he considered there was a connexion between the deposition and the pregnant state. It does not appear, however, that the phenomenon has been observed in other countries. According to Rokitansky, the bony layer is generally deposited on the inner surface of the frontal and parietal bones; but, at times, it spreads over the whole of the inner surface of the cranium; and islets (*insulæ*) of it are observed on the base of the cranium.

The urine of the pregnant female has been found to contain a peculiar substance, which separates and forms a pellicle on the surface. To observe this, it must be allowed to stand from two to six days, when minute opaque bodies are observed to rise to the surface, where they gradually agglomerate and form a continuous layer which is so consistent that it may be almost lifted off by raising it by one of its edges. To this pellicle the name *kiestein* or more properly *kyestein* (from κυειν, "to be pregnant," and εσθης, "a pellicle,") has been given. It is whitish; opalescent; slightly granular, and may be compared to the fatty substance that swims on the surface of soups, after they have been allowed to cool. When examined by the microscope, it has the aspect of an amorphous mass, consisting of minute opaque corpuscles intermingled with crystals of ammoniaco-magnesian phosphate. The kyestein remains on the surface for several days; the urine then becomes turbid, and small opaque masses are detached from the kyestein and fall to the bottom of the fluid; the pellicle then soon becomes destroyed. The author has distinctly noticed in some of the cases the cheesy odour of kyesteinic urine described by Dr. Bird. M. Simon[1] found the whole field of vision bestrewed with numerous vibriones in active motion, and crystals of ammoniaco-magnesian phosphate. M. Zimmerman,[2] too, states, that kyestein consists almost entirely of vibriones. These animalcules, he says, are first formed in the lower strata of the urine, which they render turbid. They then rise, in quantities, to the surface, where they form, with crystals of ammonio-phosphate of magnesia, amorphous phosphate of lime and urate of ammonia, the yellowish white pellicle—the kyestein.

Various experiments have been made on this matter, and its value as an index of the pregnant condition, by MM. Nauche,[3] Eguisier,[4] Dr. Golding Bird,[5] Mr. Letheby,[6] Dr. Stark,[7] the author's friend Dr. E. K. Kane,[8] of the United States Navy; and, at the author's request, by Drs. McPheeters and Perry,[9] at the time resident physicians at the

[1] Animal Chemistry, Sydenham Society edition, ii. 331, Lond., 1846, or Amer. edit., Philad., 1846.

[2] Cited from Casper's Wochenschrift, May 30 and June 6, 1846, in Lond. Med. Gaz., Sept., 1846.

[3] La Lancette Française, and Lond. Lancet, No. clxvii. p. 675.

[4] La Lancette Française, Février 21, 1839; also, L'Expérience, Juillet 25, 1839.

[5] Guy's Hospital Reports, April, 1840; and Urinary Deposits, 2d Amer. edit., p. 287, Philad., 1851.

[6] London Medical Gazette, Dec. 24, 1841.

[7] Edinb. Med. and Surg. Journal, Jan., 1842.

[8] American Journal of the Med. Sciences, p. 37, July, 1842.

[9] Amer. Med. Intel., March 15, 1841, p. 369.

Philadelphia Hospital, and by M. Kleybolte.[1] They show, that when taken in conjunction with other phenomena, the appearance of kyestein is certainly a valuable aid in the diagnosis of pregnancy. Mr. Letheby found unquestionable evidence of it in 48 out of 50 cases between the 2d and 9th months, and was unable to account for its absence in the two exceptional cases. The result of Dr. Kane's observations, which the author had an opportunity of examining from time to time, and for the accuracy of which he can vouch, was deduced by Dr. Kane as follows. *First.* Kyestein is not peculiar to pregnancy, but may occur whenever the lacteal elements are secreted without a free discharge from the mammæ. *Secondly.* Although it is sometimes obscurely developed and occasionally simulated by other pellicles, it is generally distinguishable from all others. *Thirdly.* Where pregnancy is possible, the exhibition of a clearly defined kyesteinic pellicle is one of the least equivocal proofs of that condition; and *Fourthly.* When the pellicle is not found in the more advanced stages of supposed pregnancy, the probabilities, if the female be otherwise healthy, are as 20 to 1 (81 to 4) that the prognosis is incorrect. M. Simon,[2] who has made many observations on the subject, goes farther than Dr. Kane. "From the observations of Kane and myself," he remarks, "it seems to follow, that pregnancy may exist without the occurrence of kyestein in the urine. If, however, there is a probability or possibility of pregnancy, and kyestein is found, then the probability is reduced almost to a certainty."

By means of ether, Dr. Lehmann[3] succeeded in extracting from kyestein no inconsiderable quantity of a semi-solid fat, which, when saponified by potassa, and decomposed by sulphuric acid, emitted a decided odour of butyric acid. The residue of the film, which was insoluble in ether, showed, on examination, that it was a protein compound differing in its properties from albumen. Dr. Lehmann concludes, that kyestein is no new peculiar substance; and that it is nothing more than a mixture of butyraceous fat, phosphate of magnesia, and a protein compound resembling casein.

Along with the signs already mentioned, the uterus gradually enlarges; and, about the end of the eighteenth week, sooner or later, *quickening*, as it is usually but erroneously termed, takes place, or the motion of the child is first felt. Prior to this,—from the moment, indeed, of a fecundating copulation,—the female is *quick* with child, but it is not until then, that the fœtus has undergone the developement necessary for its movements to be perceptible. This occurrence establishes the fact of pregnancy, whatever doubts may have previously existed. Where there is much corpulence, or where the fluid surrounding the fœtus is in such quantity as to throw obscurity around the case, it may be necessary, for the purpose of verifying the existence of pregnancy, to institute an examination *per vaginam.* This can rarely afford

[1] Casper's Wochenschrift, Jan. 11, 18, 1845, cited by Dr. Charles West, in Brit. and For. Med. Rev., Oct., 1845, p. 525.

[2] Op. cit.

[3] Lehrbuch der Physiologischen Chemie, 2ter Band., S. 420, Leipz., 1850; or Amer. edit. of Dr. Day's Translation, by Dr. Robt. E. Rogers, ii. 136, Philad., 1855; and Handbuch der Physiologischen Chemie, S. 193, Leipz., 1854: or translation by Dr. J. Cheston Morris, p. 198, Philad., 1856.

much evidence prior to the period of quickening; but, after this, the examination, by what the French term the *mouvement de ballottement*, may indicate the presence or the contrary of a fœtus in utero. This mode of examination consists in passing the forefinger of one hand into the vagina,—the female being in the erect attitude,—and giving the fœtus a sudden succussion by means of the other hand placed on the abdomen. In this way, a sensation is communicated to the finger in the vagina, which is often of an unequivocal character. During the latter months, the cervix uteri becomes progressively shorter.

The application of the stethoscope has been advantageously used as a means of discrimination in doubtful cases. By applying this instrument to the abdomen of a pregnant female, after the fifth month, the pulsations of the fœtal heart are audible. This instrument may also indicate when the pregnancy is multiple, by the distinct pulsations of two or more hearts; according as it is double, triple, &c. It would appear, however, that auscultation affords but two main signs of pregnancy,—the pulsations of the fœtal heart, and a murmur, which, according to some, should, correctly speaking, be designated "uterine *souffle* or murmur." This murmur has been supposed to take place in the uterine artery, which serves for the nutrition of the placenta, and even to indicate the situation of the placenta; others have considered, that it is not connected with the placenta, but depends upon the increased vascularity and peculiar arrangement of the uterine vessels during the gravid state; but it has been questioned whether it be ever produced except by pressure on the maternal vessels. It is, indeed, positively stated, that the sound has been heard in cases of uterine and other tumours where there was no pregnancy; and in one case of fibrous tumour of the uterus, the author certainly heard it distinctly.

In addition to the placental or uterine murmur and the sounds of the fœtal heart, a third sound is occasionally heard, and one which is considered to be seated in the umbilical cord. This has been termed the "funic bellows' sound." It is of the bellows species; is synchronous with the first sound of the fœtal heart, and appears to depend upon a diminution in the caliber of the umbilical arteries, either through pressure, or stretching of the funis, or both combined. It is affirmed, too, by Prof. Nägele, that the movements of the fœtus may be distinguished by the stethoscope at a very early period of pregnancy.

The pulsations of the fœtal heart vary from 120 to 180 in the minute. Nägele[1] affirms, that he has occasionally found them,—momentarily however,—sink as low as 50 or 60. Professor Hamilton[2] refers to various cases, in which Drs. Sidey and Moir attended particularly to the action of the fœtal heart previous to breathing, in all of which its beats were 60 or less in a minute, before the establishment of respiration. Professor Hamilton affirms, that almost half a century had then elapsed since he remarked, that in infants which did not breathe upon birth, but in which the pulsation of the cord continued, the action of the heart did not exceed 60 pulsations in the minute till breathing took place, and then it became so frequent that it could not be numbered.

[1] Dublin Journal of Medical Science, Jan., 1838.

[2] Practical Observations on Various Subjects relating to Midwifery, American Medical Library edition, part i. pp. 51, 97, and part ii. p. 123, Philad., 1837–8.

This led him to take every opportunity—when he had occasion to introduce his hand into the uterus to extract the infant—to endeavour to ascertain the action of the heart before birth, and he in no instance discovered it to be more frequent than in the still-born infant whose cord pulsates. Yet neither Dr. Hamilton, nor any one of the gentlemen referred to, denies that pulsations, which have been referred to the fœtal heart, are heard by the stethoscope, varying from 120 to considerably upwards in the minute. The truth would seem to be, that in the cases examined by Professor Hamilton, owing to the influence of the parturient efforts on the innervation, and through it on the circulation of the fœtus, the pulsations of the fœtal heart were unusually depressed; but in every case, he would, doubtless, have found them isochronous with those of the umbilical cord, had he made the experiment. It is obvious, indeed, that they must be so, seeing that the umbilical arteries are but a part of the circulatory apparatus of the fœtus. In a case observed, at the author's request, by Dr. Vedder, then resident physician at the Philadelphia Hospital, it was noticed, that whilst the uterus was quiescent, the pulsations of the fœtal heart numbered 140 per minute; but that immediately succeeding a pain they were only 96, and gradually rose to 140. After delivery, the cord and fœtal heart beat respectively 134 in the minute.[1] Von Hoefft,[2] of St. Petersburg, has seen the influence of uterine contraction on the circulation of the fœtus exhibited in the most marked manner. During slight pains, the pulsations of the fœtal heart continue, but during more violent contractions, especially after the discharge of the waters, they are wholly interrupted, so that the fœtus may be presumed to be in a state of temporary asphyxia in the last periods of labour, and great danger may threaten it if the pains continue for a long time without interruption. The remarks of Professor Hamilton ought, therefore, to have no weight with the observer. They were imperfect, inasmuch as the pulsations of the fœtal heart were not attended to, whilst he numbered the beats of the cord; and, consequently, they conflict in no respect with the observations of other obstetrical physiologists, which show, that the sounds usually heard during pregnancy, and referred to the fœtal heart, are actually owing to the pulsations of that organ.

A case of triplets has been published in which the pulsations of three distinct fœtal hearts were clearly detected.

Lastly; many uneasy feelings, attendant upon gestation, are owing to the increased size of the uterus. These occur more especially during the latter half of pregnancy. The parietes of the abdomen may not yield with the requisite facility, so that pain may be experienced, especially at the part where the soft parietes join the false ribs. The pressure of the uterus upon the vessels and nerves of the lower extremities occasions enlargement of the veins of the legs; transudation of the serous part of the blood into the areolar tissue, so as to cause considerable swelling of the feet and ankles; numbness or pricking of the lower limbs, and the most violent cramps, especially when the female is in the recumbent posture, so that she may be compelled to rise suddenly from bed several times in the course of the night. The same pressure

[1] American Medical Intelligencer, Jan. 15, 1839, p. 311.

[2] Ibid., April 15, 1839, p. 31; also, Neue Zeitschrift für Geburtskunde, B. vi. S. 1.

exerted on the bladder and rectum, especially during the latter months, brings on a constant desire to evacuate the contents of those reservoirs.

h. *Duration of Pregnancy.*

The duration of human pregnancy has given rise to much discussion amongst medico-legal and obstetrical physiologists; and opinions still fluctuate. In the years 1825–6, a case occurred before the House of Lords, which exhibits this discordance in a striking point of view. It was the Gardner Peerage cause, in which the principal accoucheurs of the British metropolis,—including Sir Charles M. Clarke, Drs. Blegborough, D. Davis, A. B. Granville, Conquest, Merriman, Hopkins, Blundell, and Power,—were examined. Of seventeen medical gentlemen, who gave evidence, five maintained the opinion, that the period of human utero-gestation is limited to about nine calendar months,—from thirty-nine to forty weeks, or from two hundred and seventy to two hundred and eighty days,—and of course considered it to be an impossibility, that the claimant could have been the product of a three hundred and eleven days' gestation. On the other side, of twelve medical gentlemen, all of whom appeared to agree that nine calendar months is the usual term of utero-gestation, most of them maintained the possibility, that pregnancy might be protracted to nine and a half, ten, or even eleven calendar months, and were, of course, in favour of the claimant in the cause.[1]

The difficulty, that arises in fixing upon the precise term, is owing to the impracticability, in ordinary cases, of detecting the time of conception. But few cases exist where conception can be dated from a single *coitus*.[2] An opportunity occurred, however, to Dr. Montgomery,[3] for observing the term of utero-gestation under circumstances admitting of no dispute. A lady, who had been for some time under his care, in consequence of irritable uterus, went to the seaside at Wexford, in the month of June, leaving her husband in Dublin. They did not meet again until the 10th of November, when he went to visit her, and, being engaged in a public office, returned to town on the following day. Conception followed his visit, and before the end of the month she began to experience some of the signs of pregnancy, and on the 28th of January she quickened. Her last menstruation had occurred on the 18th of October, or twenty-three days before the visit of her husband; and on the 17th of August she was delivered. Parturition in this case occurred exactly two hundred and eighty days from the time of conception.

The sensations of the female are fallacious guides; and, accordingly, as has been previously remarked, she is usually in the habit of reckoning from ten days after the disappearance of the catamenia; but impregnation might have taken place on the very day after their cessation, or

[1] The Medical Evidence, relative to the Duration of Human Pregnancy, as given before a Committee of the House of Lords, in 1825 and 1826, with notes, by Robert Lyall, M. D., Lond., 1826.

[2] For some such, see Guy, Principles of Forensic Medicine, P. 1, p. 167, London, 1843, and Taylor, Medical Jurisprudence, 3d Amer., by Dr. E. Hartshorne, p. 468, Philad., 1850.

[3] An Exposition of the Signs and Symptoms of Pregnancy, &c., p. 257, Lond., 1837.

not until a day prior to the subsequent period; so that, in this way, an error of at least ten days may occur in the estimate; and again, it does not *always* happen, that the menstruation, immediately succeeding, is arrested. The period of quickening, which generally happens about the eighteenth week of utero-gestation, does not afford us more positive evidence, seeing that it is liable to vary; being experienced by some females earlier, and by others somewhat later. We are, however, justified in stating, that the ordinary duration of human pregnancy is ten lunar months or *forty weeks;* but we have no less hesitation in affirming, that it may be protracted, in particular cases, much beyond this. We find in animals, where the date of impregnation can be rigidly fixed, and the usual term determined without difficulty, that numerous cases are met with in which the period is protracted, and there is no reason to doubt, that the same thing happens to the human female. Earl Spencer has communicated the results of his observations on cows for a number of years to the English Agricultural Society.[1] Of 764, 314 calved before the 284th day, and 310 after the 285th; so that the probable period of gestation, he thinks, ought to be considered 284 or 285 days, and not 270, as stated in the book upon Cattle, published under the superintendence of the Society for the Diffusion of Useful Knowledge. The extremes in his observations were 220 and 313 days. In the observations of Mr. C. N. Bement, of Albany, cited by Dr. T. R. Beck,[2] the extremes in sixty-two observed cases were 213 and 336. Mr. Bement, however, doubts the accuracy of the first, for in no other instance did the period fall below 260 days.

The observations of Earl Spencer[3] have suggested an interesting question in regard to man. He noticed, that cows in calf to a particular bull belonging to him carried their calves about four days longer than those in calf to any other bull;—the average period of gestation being in them 290¼ days.

In a case detailed by Dr. Dewees,[4] an opportunity occurred for dating with precision the time of fecundation. The case is likewise interesting in another respect, as demonstrating, that fecundation does not necessarily arrest the succeeding catamenial discharge. The husband of a lady, who was obliged to absent himself many months, in consequence of the embarrassment of his affairs, returned one night clandestinely,—his visit being known only to his wife, her mother, and Dr. Dewees himself. The lady was, at the time, within a week of her menstrual period; and, as the catamenia appeared as usual, she was induced to hope, that she had escaped impregnation. Her catamenia did not, however, make their appearance at the next period; the ordinary signs of pregnancy supervened; and in nine calendar months and thirteen days from the visit of her husband, she was delivered. In his evidence before the House of Peers, in the case before alluded to, Dr. Granville stated his opinion, that the usual term of utero-gestation is as we have given it; but he, at the same time, detailed the case of his own lady, in whom it had been largely protracted. Mrs. Granville passed her menstrual period on the 7th of April, and on the 15th of August fol-

[1] Journal of the English Agricultural Society, part ii., 1839.
[2] American Journal of the Medical Sciences, Oct., 1845, p. 520.
[3] Hall, Lond. Med. Gazette, May 6, 1842.
[4] A Compendious System of Midwifery, 10th edit., p. 130, Philad., 1843.

lowing she quickened;—that is, four months and six or seven days afterwards. In the early part of the first week in January her confinement was expected, and a medical friend desired to hold himself in readiness to attend. Labour pains came on at this time, but soon passed away; and she went on till the 7th of February, when labour took place, and was speedy. The child was larger and stronger than usual, and was considered by Dr. Granville,—as well as by Dr. A. T. Thomson, Professor of Materia Medica in the University of London,—to be a ten months' child. Now, if, in this case, we calculate, that conception occurred only the day before the interruption of menstruation, three hundred and six days must have elapsed between impregnation and birth; and if the middle period between the last menstruation and the interruption be taken, the interval must have been three hundred and sixteen, or three hundred and eighteen days. A similar case has been related by Dr. R. H. McIlvain,[1] of North Carolina. A woman, of character above suspicion, on the 1st of July, 1847, had intercourse with her husband, whose business had compelled him to absent himself for more than a year in a distant State. On the nights of the 2d, 3d, and 4th of July, the intercourse was repeated; but not subsequently. On the 23d of April, 1848, she was delivered of a child, which weighed nine pounds. Now, if fecundation had occurred on the 1st of July, the duration of pregnancy must have been 296 days; if on the 4th, 293 days. Dr. McIlvain adds, that the large size of the child was in favour of gestation having been longer than usual. The woman had borne three children previously, none of which weighed more than eight pounds.

Of recorded cases of single coitus, which are, of course, most to be relied on, Dr. James Reid[2] found 293 days to form the longest period, or eighteen days beyond what he has deemed to be the average duration of pregnancy in the human female; and he remarks it to be a coincidence with the results of Lord Spencer's tables, that of the 764 cows, the greatest excess beyond the average term of gestation in them —285 days—was also eighteen days.

The limit, to which the protraction of pregnancy may *possibly* extend, cannot be assigned. It is not probable, however, that it ever varies largely from the ordinary period. The University of Heidelberg allowed the legitimacy of a child, born at the expiration of thirteen months from the date of the last connubial intercourse; and a case was decided by the Supreme Court of Friesland, by which a child was admitted to the succession, although it was not born till three hundred and thirty-three days from the husband's death; or only a few days short of twelve lunar months. These are instances of judicial philanthropy, and, perhaps, we might add, credulity. Still, although extremely improbable, we cannot say that they are impossible. This much, however, is clear, that real excess over two hundred and eighty days is by no means frequent; and we think, in accordance with the civil code now in force in France, that the legitimacy of an infant, born three hundred days after the dissolution of marriage, may be contested; although we are by no means disposed to affirm, that if the character of the woman be irreproachable, the decision should be on the side of illegitimacy. Pro-

[1] American Journal of the Medical Sciences, July, 1848, p. 247.
[2] Lancet, July 20, 1850; and Amer. Journ. of the Medical Sciences, Oct., 1850, p. 522.

fessor Hamilton, indeed, says he is "quite certain," that the term allowed by the French code is too limited, and is inclined to regard *ten calendar months*, which he believes to be the established usage of the Consistorial Court of Scotland, as a good general rule, liable to exceptions upon satisfactory evidence that menstruation had been obstructed for a certain period.[1]

In the year 1844, a case of gestation protracted to 317 days was admitted in Cambria county, Pennsylvania;[2] and in 1846, another of 313 days at the Lancaster Quarter Sessions.[3] The charge of the presiding judge, Ellis Lewis, in the latter case, was sound and satisfactory. Whilst he expressed the belief, that protracted gestation for the period of 313 days is *unusual* and *improbable*, he regarded it as not *impossible;* but properly added "that the evidence to establish the existence of such a departure from the usual period should be clear and free from doubt."

A like uncertainty exists as to the earliest period at which a child is *viable* or capable of carrying on an independent existence. The period is generally fixed at near the end of the seventh month; but children have lived for some time, that have been born earlier. Much evidence was brought forward in a case in Scotland, to show that it is possible for a child that was born at the conclusion of 24 weeks of utero-gestation to live some months. In that case, the Presbytery decided in favour of the legitimacy of one born alive within 25 weeks after marriage.[4]

An interesting case has been published in this country by Dr. Shipman.[5] A woman, who considered herself to be at the commencement of the sixth month of utero-gestation, was prematurely delivered in consequence of a fall. The appearance of the child indicated no farther advance. It was barely alive, with little motion, and was too feeble to cry; had no nails; no hair; and the cranium was imperfectly ossified. At the end of the seventh week, it was weighed for the first time, when its weight was found to be one pound ten ounces, which Dr. Shipman thinks was probably the true weight when it was born. When ten months old it weighed ten pounds eight ounces, and was lively, playful, and healthy. It was not measured at the time of birth, and no hopes of its living were entertained.[6]

The difficulty, in such cases, of fixing the exact date of conception must necessarily render all computation in regard to the precise age of the child uncertain.[7]

[1] Op. cit., Amer. Med. Library edit., p. 59.

[2] Commonwealth *vs.* Jeremiah Wilson Porter; indicted for Fornication and Bastardy, January Term, 1844; reported by Dr. A. Rodrigue, in American Journal of the Medical Sciences, Oct., 1845, p. 338.

[3] Commonwealth *vs.* Elijah F. Hoover; in Medical Examiner, for June, 1846, p. 381; and in American Journal of the Medical Sciences, for Oct., 1846, p. 536.

[4] Lond. Med. Gaz., xvii. 92.

[5] American Journal of the Med. Sciences, April, 1843, p. 499.

[6] For the case of a child born at the commencement of the sixth month, and reared, see Barker, American Journal of the Medical Sciences, Jan., 1851, p. 257; and for other cases, see Taylor, Medical Jurisprudence, 3d Amer. edit., by Dr. E. Hartshorne, p. 403, Philad., 1853.

[7] See, on all this subject, Prof. Simpson, Edinb. Monthly Journal of Med. Science, July, 1853, p. 50; and Obstet. Memoirs and Contrib., p. 329, Edinb., 1855, or Amer. edit., Philad., 1855.

i. *Parturition.*

At the end of seven months of utero-gestation, and even a month earlier, the fœtus is capable of an independent existence; provided, from any cause, delivery should be hastened. This is not, however, the *full period*, and although labour may occur at the end of seven months, the usual course is for the fœtus to be carried until the end of about ten lunar months. If it be extruded prior to the period at which it is able to maintain an independent existence, the process is termed *abortion* or *miscarriage;* if between this time and the full period, it is called *premature labour.* From certain records, abortion or premature labour has been estimated to occur, on the average, once in 78⅔ cases. In the Gebäranstalt of Vienna, the inmates of which are chiefly unmarried, the ratio appears to be more than double, or 1 in 38·13.[1]

With respect to the causes, that give rise to the extrusion, we are in utter darkness. It is in truth as inexplicable as any of the other instinctive operations of the living machine. Yet although this is generally admitted, the discussion of the subject occupies a considerable space in the works of some obstetrical writers. Our knowledge appears to be limited to the fact, that when the fœtus has undergone a certain degree of developement, and the uterus a corresponding distension and organic change, its contractility is called into action, and the uterine contents are beautifully and systematically expelled. Nor can we pronounce upon the degree of distension, nor appreciate the organic changes that shall give occasion to the exertion of this contractile power. At times, it supervenes after a few months of utero-gestation so as to produce abortion: at others, it happens when the fœtus is just *viable;* and at others, again, and in the generality of cases, is not elicited until the full period. In cases of twins the uterus will admit of still greater distension before its contractility is aroused.

It has been maintained by M. Berthold,[2] Dr. Tyler Smith,[3] and M. Leray,[4] that parturition, like menstruation, is an ovarian phenomenon; that the muscular excitability of the uterus at the full period is dependent upon ovarian excitement; and that the supervention of its expulsive contractions on the 280th day, or thereabouts, after conception, is a reflex phenomenon, of which the eleventh periodical access of ovarian excitement, corresponding to the eleventh menstrual period, is the exciting cause; but the evidence brought forward in support of the position is far from establishing it. The hypothesis would require a more extensive inquiry into the phenomena, presented not only by the human female, but by animals, in which the period of parturition would have to be a multiple of the period of œstruation or heat; for it has been before remarked that the œstruation of animals and menstruation have been regarded as the same form of ovulation. Dr. Smith affirms, that observation of animals has tended to confirm the view;

[1] Wilde, Austria, &c., p. 222, Dublin, 1843.

[2] Comptes Rendus, 27 Mai, 1844; and Archives Générales de Médecine, Juin, 1844.

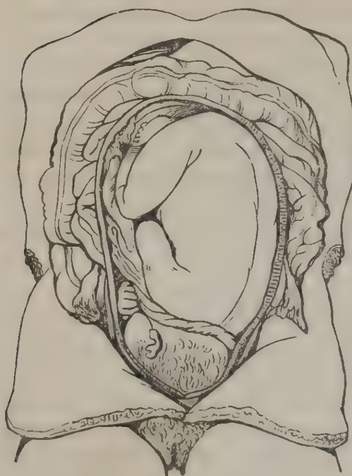
[3] Parturition and the Principles and Practice of Obstetrics, Amer. edit., p. 127, Philad., 1849.

[4] Cited in London Lancet, Jan., 15 1848.

but he does not furnish the facts in sufficient number to lead to anything like conviction of the truth of the hypothesis.

On the other hand, Dr. Carpenter considers the hypothesis to be distinctly negatived by the following facts. *First.* The period of gestation, although commonly a multiple of the menstrual interval, is by no means constantly so; the former often remaining normal, when the latter is shorter or longer than usual. *Secondly.* Parturient efforts take place in the uterus, notwithstanding the previous removal of the lower part of the spinal cord. *Thirdly.* The removal of the ovaries in the latter part of gestation does not interpose the least check to the parturient action, as Professor Simpson, of Edinburgh, has experimentally ascertained. Dr. Carpenter forcibly adds, that he considers himself fully justified in asserting that "this hypothesis does not possess the slightest claim to be entertained as even a *possible* one."[1]

Fig. 449.



Natural Labour.

In regard to the action of the muscles specially concerned in the process, it would seem, that the diaphragm and abdominal muscles are excited to action through an excitor influence conveyed from the uterus to the spinal cord; whilst the contractions of the uterus take place independently of all connexion with the nervous centres,—like the peristole of the intestines, and the systole of the ventricles of the heart. The fœtus has been observed to be expelled after the cessation of the respiratory movements of the mother. This, as has been suggested,[2] has probably occurred in consequence of the uterine fibres retaining their power of contraction longer than those of muscles supplied by cerebro-spinal nerves.

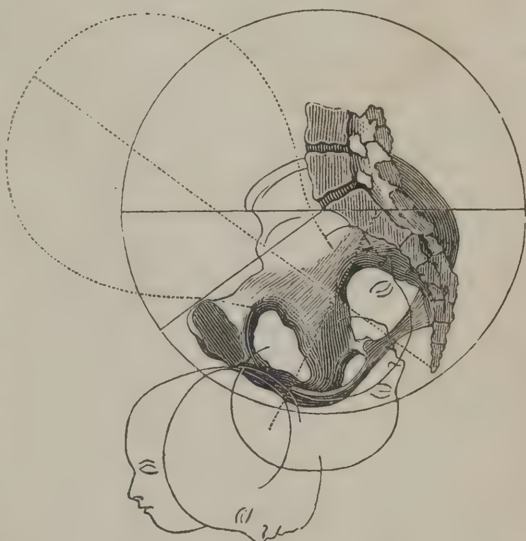
A day or two preceding labour, a discharge is occasionally observed from the vagina of a mucous fluid more or less streaked with blood. This is termed the *show*, because it indicates the commencement of dilatation of the neck, or mouth of the womb,—the forerunner of *labour* or *travail.* The external organs at the same time become tumid and flabby. The orifice of the uterus, if an examination be made, is perceived to be enlarging; and its edges are thinner. Along with this, slight grinding pains are experienced in the loins and abdomen. After an uncertain period, pains of a very different character come on, which commence in the loins, and appear to bear down towards the os uteri. These are not constant, but recur at first after long intervals, and subsequently after shorter,—the body of the uterus

[1] Brit. and For. Med.-Chir. Rev., July, 1849, p. 1; and Carpenter, Principles of Human Physiology, Amer. edit., p. 776, note, Philad., 1855.
[2] Carpenter, Human Physiol., p. 153, Lond., 1842.

manifestly contracting with great force, so as to press the ovum down against the mouth of the womb, and dilate it. In this way, the membranes protrude through the os uteri with their contained fluid, the pouch being occasionally termed *bag of waters.* Sooner or later, the membranes give way; *the waters* are discharged, and the uterus contracts so as to embrace the body of the child, which was previously impracticable, except through the medium of the liquor amnii.

At the commencement of labour, the child's head has not entered the pelvis, the occiput being generally towards the left acetabulum; but when the uterine contractions become more violent, and are accompanied by powerful efforts on the part of the abdominal muscles, the head enters the pelvis; the mouth of the womb becomes largely dilated, and the female is in a state of agitation and excitement, owing to the violence of the efforts and the irresistible desire she has of assisting them as far as lies in her power. When the head has entered the pelvis, in the position in which the long diameter corresponds to the long diameter of the pelvis, it describes, laterally, an arc of a circle, the face passing into the hollow of the sacrum, and the occiput behind the arch of the pubis. By the continuance of the pains, the head presents at the vulva. The pains now become urgent and forcing. The os coccygis is pushed backwards, and the perineum is distended,—at times so considerably as to threaten, and even undergo laceration; the anus is also forced open and protruded; the nymphæ and carunculæ of the vagina are effaced; the labia separated, and the head clears the vulva, from the occiput to the chin, experiencing a vertical rotation as depicted in Fig. 450. When the head is extruded, the shoulders and rest of the body readily follow on account of their smaller dimensions. The child, however, still remains attached to the mother by the navel-string, which has to be tied, and divided at a few fingers' breadth from the umbilicus. After the birth of the child, the female has generally a short interval of repose; but after a time, slight bearing down pains are experienced, owing to the contraction of the uterus for the separation of the placenta and membranes of the ovum, called the *secundines* or *after-birth.*

Fig. 450.



Rotation of the Head in its exit.

The process of parturition is accomplished in a longer or shorter time in different individuals, and in the same individual in different labours, according to the particular conditions of the female and fœtus. The parts, however, when once dilated, yield much easier afterwards to similar efforts, so that the first labour is generally the most protracted. After the separation of the secundines, the female is commonly left in a state of debility and fatigue; but this gradually disappears. The uterus also contracts; its vessels become tortuous, small, and their orifices are plugged up. For a short time, blood continues to be discharged from them; but as they become obliterated by the return of the uterus to its usual size, the discharge loses its sanguineous character, and is replaced by one of a paler colour, called *lochia*, which gradually disappears, and altogether ceases in the course of two or three weeks after delivery. For a day or two after delivery, coagula of blood form in the interior of the uterus, especially in the second and subsequent labours, which excite the organ to contraction for their expulsion. These contractions are accompanied with pain, and are called *after-pains;* and as their object is the removal of that which interferes with the return of the uterus to its proper dimensions, it is obvious that they ought not to be officiously interfered with.

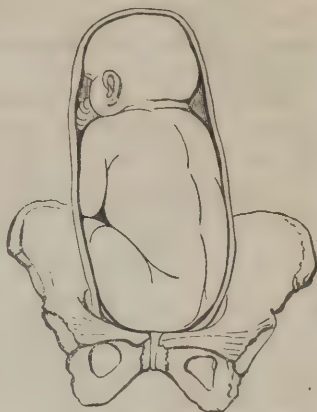
Whilst the uterus is contracting its dimensions, the other parts gradually resume the condition they were in prior to pregnancy; so that, in the course of three or four weeks, it may be impracticable to pronounce positively whether delivery has recently taken place or not. The presence of shining broken streaks, like the remains of cracks, in the skin of the abdomen, caused by previous distension of the abdominal parietes, has been regarded as a sign of some value of former delivery; but they are often wanting where delivery has really taken place; and it will be readily understood, that any cause of distension may produce them. These marks are sometimes accompanied by a brown line, extending from the pubis to the umbilicus;[1] and accompanying this dark abdominal line, Dr. Montgomery, in a few instances, has observed another appearance of a similar kind, which consists of a dark coloured circle or areola surrounding the umbilicus, extending in breadth about a quarter of an inch all around it, and generally, but not always, varying in depth of tint according to the colour of the hair, eyes, and skin of the woman. Unlike the mammary areola, there is no turgescence or elevation of it above the surface of the surrounding skin, nor are there any prominent follicles upon its disk. Whether it be ever produced under circumstances unconnected with pregnancy remains to be determined by farther observation.

Labour, as thus accomplished, is more deserving of the term in the human female than in animals; and this is partly owing to the large size of the fœtal head, and partly to the circumstance, that in the animal the axis of the pelvis is the same as that of the body; whilst in the human female, the axis of the brim, as represented by the dotted straight lines in Fig. 450, forms a considerable angle with that of the

[1] Montgomery, Signs and Symptoms of Pregnancy, 6th edit., p. 171, Lond. 1842; Dublin Journal of Med. Science, May, 1844, p. 298: see, also, Dr. R. Turner. Lond. and Edinb. Monthly Journal of Med. Science, Aug., 1842, and Sept., 1844; and Dr. J. R. Cormack, Ibid., Feb., 1844.

outlet. In rare cases, the child is extruded without labour-pains. The author was called in the night to a female, who declared to him, that she was awakened by a slight abdominal uneasiness, when she found both the child and secundines expelled; and other cases of a like kind are on record. These facts should be borne in mind in cases of alleged infanticide.

Fig. 451.



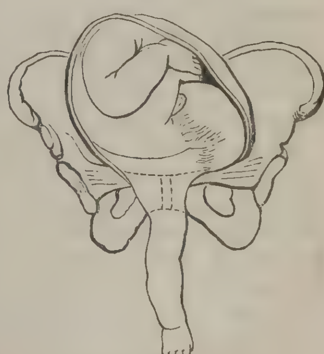
Breech Presentation.

The duration of labour varies according to numerous circumstances. There is reason to believe, that it is more tedious in civilized than in savage life; and in colder than in warmer climates. The following table is the result of 311 observed cases in the Edinburgh Royal Maternity Hospital, as reported by Professor Simpson.[1] It reads thus:—the whole labour was completed in one hour in four cases; in two hours in four cases, and so on.

Duration in hours.	Whole labour.	Duration in hours.	Whole labour.
1	4	13	23
2	4	14	14
3	7	15	8
4	16	16	6
5	17	17	6
6	16	18	8
7	28	19	10
8	21	20	3
9	17	25	22
10	20	30	12
11	20	35	5
12	12	Above 36	14

The position of the child—with the face behind and the occiput before—constitutes the usual presentation in natural labour. Of twelve thousand six hundred and thirty-three children born at the *Hospice de la Maternité* of Paris, twelve thousand one hundred and twenty, according to M. Jules Cloquet, were of this presentation; sixty-three had the face turned forward; one hundred and ninety-eight were breech presentations (Fig. 451); in one hundred and forty-seven the feet presented; and in three, the knees. All these, however, are cases in which labour can be effected without assistance; the knee and feet presentations being identical—as regards the process of de-

Fig. 452.



Arm Presentation.

[1] Monthly Journal and Retrospect of the Medical Sciences, Nov., 1848, p. 333.

livery—with that of the breech. But, whenever any other part of the fœtus presents, the position is unfavourable and requires that the hand should be introduced into the uterus, with the view of bringing down the feet, and converting the case into a foot presentation. The marginal figure of a presentation of the right superior extremity sufficiently shows, that labour could not be accomplished without the efforts of art.

The following table, drawn up from data furnished by M. Velpeau,[1] shows the comparative number of presentations, according to the experience of the individuals mentioned.

TABLE EXHIBITING THE RATIO OF PRESENTATIONS IN 1000 CASES.

	According to							
	Merriman.	Bland.	Mde. Boivin.	Mde. Lachapelle.	Nägele.	Lovati.	Hospital of the Faculté.	Boer.
Regular, or of the vertex,	924	944	969	933	933	911	980	
I. *Occipito-anterior*, . .	908		944	910		895		
a. Occipito-cotyloid, (left)			760	717		537		
Do. (right)			· 179	209				
b. Occipito-pubian, . .			0·29					
II. *Occipito-posterior*, . .			9·4	9				
a. Fronto-cotyloid (left) .			5·3	7·3				
b. Do. (right)			4·4	2·9				
Face presentation, . .	2·2	2·6	3·6	4·6				8·8
Mento-iliac (right) . .				2·6				
Of the pelvis, ...	36	28	29	36	47			29
Of the foot, ...	12·7	9·4		14				10·3
Of the knees, ...			0·19	0·40				
Of the breech, ...	23	13	18	22				19
Of the trunk, ...			4·6	5.3	4·8			
Requiring Forceps, . .	6·6	4·7	4·6	3.4	3·6			5·7
——— Turning, . .	16	4·7		7.8	7·2			5·9
——— Cephalotomy,	3·3	5·2	4·77	0·53	2·4			1·5

In twin labours, the children may both present by the head; or one by the head and another by the breech, or both be footling cases.

It is found, that the period of the twenty-four hours has some influence upon the process of parturition;—about five children being born during the night for four during the day. Of 2,019 births, according to Wedl,[2] 780 occurred from 11 at night until 7 in the morning; 680 from 7 in the morning until 3 in the afternoon; and 577 from 3 until 11 at night.

The parturient and child-bed condition is not devoid of danger to the female; yet the mortality is less than is generally perhaps imagined. In some of the great lying-in institutions it has been enormous; and in the Gebäranstalt of Vienna is still estimated at 1 in 30·87! The number of deaths, during labour, and subsequently, connected therewith, has been stated to be in Berlin as 1 in 152; in Königsberg, 1 in 168; and in Wirtemberg, 1 in 175;—a proportion much less than

[1] Traité Elémentaire de l'Art des Accouchemens, Paris, 1829; or Meigs's translation, 2d edit., Philad., 1838.

[2] Canstatt's Jahresbericht, 1853, S. 236.

during the last century. In 1475 women delivered under the superintendence of the Edinburgh Royal Maternity Hospital, eleven deaths occurred, or 1 in 134.[1] Dr. Collins[2] states, that of 16,414 women, delivered in the Dublin Lying-in Hospital, 164 died, being in the proportion of 1 in 100; and if, he observes, we deduct from this number the deaths from puerperal fever, which may be considered *accidental*, the proportion becomes greatly diminished, or 1 in 156 deliveries; and again, if we subtract the deaths from causes not the results of child-birth, the mortality, from effects arising in consequence of parturition, is vastly reduced to 1 in 244. In the year 1839, childbirth was fatal to 2915 women throughout England and Wales. Of 1,000,000 females living, 368 died from this cause in 1838, and 372 in 1839. About 5 births in 1,000, it was estimated, were fatal to the mother.[3] In 1840, the ratio was greater, or about 1 in 187.[4] It has been already remarked, that these fatal cases occur more frequently in male than female births. From the returns of Drs. Clarke and Collins there are reports in the Dublin Hospital of the sex of the child in 368 cases in which the mother died from labour or its consequences. In 231, the child was male; in 137 female; or the proportion of males to females was as 168 to 100. Taking these statistical facts as data, Prof. Simpson,[5] of Edinburgh, infers, that annually, in Great Britain, "the valuable lives of 500 mothers (to speak within the terms) are lost in childbirth," through the influence and agency of the sex and size of the male infant.

Fig. 453.

Twin case.

The further details on the subject of parturition belong more appropriately to obstetrics.

j. *Lactation.*

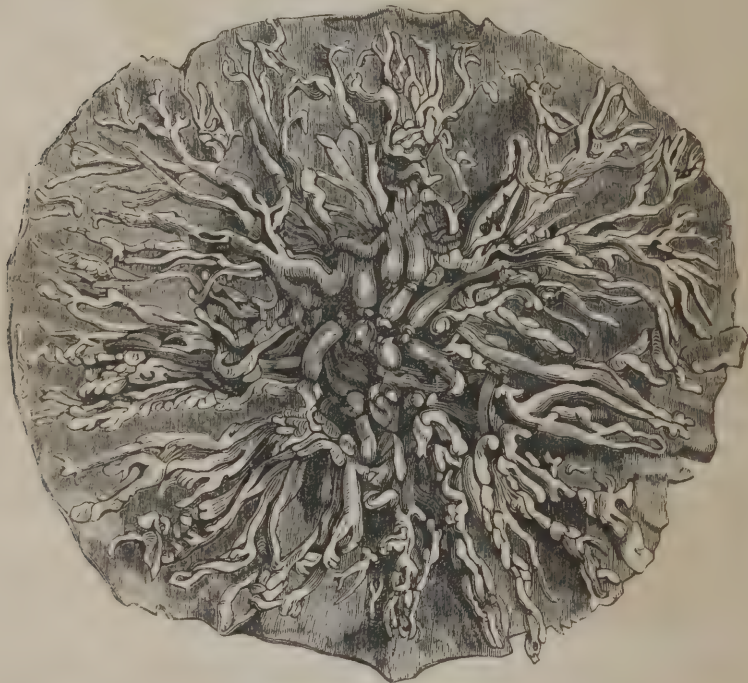
When the child has been separated from the mother, and continues to live by the exercise of its own vital powers, it has still to be dependent upon her for nutriment adapted to its tender condition. Whilst in utero, this nutriment consists of fluids placed in contact with it; but after birth a secretion serves the purpose, which has to be received into the stomach and undergo the digestive process. This secretion is the *milk*. It is prepared by the *mammæ* or *breasts*, the number, size, and situation of which are characteristic of the human species. Instances are, however, on record, of three or more distinct mammæ in

[1] Monthly Journal and Retrospect of the Medical Sciences, November, 1848, p. 337.
[2] Practical Treatise on Midwifery, p. 366, Lond., 1835.
[3] W. Farr, in Third Annual Report of the Registrar-General of Births, Deaths and Marriages in England, p. 74, London, 1841.
[4] W. Farr, in Fourth Annual Report, &c., &c., p. 219, Lond., 1842.
[5] Edinb. Med. and Surg. Journal, Oct., 1844.

the same individual. Two such are described by Dr. G. C. M. Roberts, of Baltimore.[1] At times, there are two nipples on one breast. Three cases of the kind are given by Tiedemann, and one by Dr. Chowne;[2] and a case has been recorded by M. Marotte,[3] in which there was a supernumerary mamma in each axilla. In some instances the supernumerary breasts have been on other parts of the body.

Each breast contains a mammary gland, surrounded by the fat of the breast, and resting on the pectoralis major muscle. It is formed of several lobes, united by somewhat dense areolar tissue, and consisting of smaller lobules, which seem, again, composed of round granula-

Fig. 454.



Milk Ducts in Human Mamma.

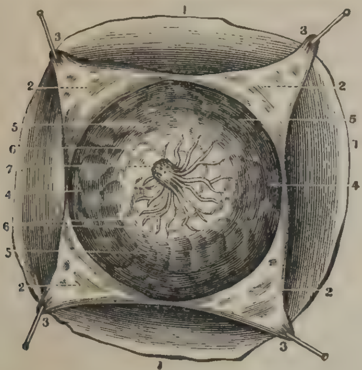
The ducts are filled with wax.

tions, of a rosy-white colour, and about the size of a poppy-seed. These granules or acini, according to Reil,[4] cannot be distinguished in the mammæ of the virgin. The glandular granules give origin to excretory ducts, called *tubuli lactiferi* seu *galactophori*, which are tortuous, extensible, and transparent; and enlarge and unite with each other, so that those of each lobe remain distinct from, and have no communica-

[1] Baltimore Medical and Surgical Journal, ii. 497, Baltimore, 1834.
[2] Lond. Lancet, July 2, 1842, p. 465.
[3] Archives Générales de Médecine, Janvier, 1850, p. 114.
[4] Schlemm, art. Brüste, in Encyclop. Wörterb. der Medicin. Wissenschaft., vi. 332 Berlin, 1831.

tion with, the ducts of any other lobe. All these finally terminate in sinuses or reservoirs, near the base of the nipple, which are fifteen or

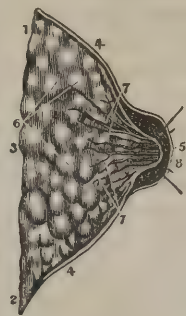
Fig. 455.



The Mammary Gland after the removal of the skin, as taken from the subject three days after delivery.

1. The surface of the chest. 2. Subcutaneous fat. 3. The skin covering the gland. 4. Circumference of the gland. 5. Its lobules separated by fat. 6. The lactiferous ducts converging to unite in the nipple. 7. The nipple slightly raised, and showing the openings of the tubes at its extremity.

Fig. 456.



A vertical section of the Mammary Gland, showing its thickness and the organs of the lactiferous ducts.

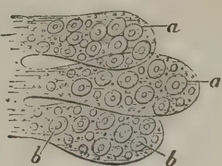
1, 2, 3. Its pectoral surface. 4. Section of the skin on the surface of the gland. 5. The thin skin covering the nipple. 6. The lobules and lobes composing the gland. 7. The lactiferous tubes coming from the lobules. 8. The same tubes collected in the nipple.

eighteen in number, and open on the nipple, without having any communication with each other. The size and shape of the breast are

Fig. 457.

Commencement of Milk Ducts as exhibited in a mercurial injection.

Fig. 458.



Ultimate Follicles of Mammary Gland.

a, a. Secreting cells. *b, b.* The Nuclei.

chiefly caused by the areolar tissue in which the mammary gland is situate: this is covered by a thin layer of skin, which is extremely soft and delicate; and devoid of folds. In the middle of the breast is the tubercle, called *nipple*, *mammella* or *teat*,—a prominence consisting of an erectile spongy tissue, differing in colour from the rest of the breast.

The nipples do not project directly forwards, but forwards and outwards, for wise purposes, which have been thus depicted by Sir Astley Cooper:[1]—"The natural obliquity of the mammella or nipple forwards and outwards, with a slight turn of the nipple upwards, is one of the most beautiful provisions in nature both for the mother and her child.

[1] On the Anatomy of the Breast, p. 12, London, 1840.

To the mother, because the child rests upon her arm and lap, in the most convenient position for sucking; for if the nipple and breast had projected directly forwards, the child must have been supported before her in the mother's hands in a most inconvenient and fatiguing position, instead of its reclining upon her side and arm. But it is wisely provided by nature, that when the child reposes upon its mother's arm, it has its mouth directly applied to the nipple, which is turned outwards to receive it, whilst the lower part of the breast forms a cushion upon which the cheek of the infant tranquilly reposes."

The erection of the nipple, which is so manifest during the process of suckling, and can be readily produced by handling it, has been supposed to be owing to an arrangement similar to that of the corpora cavernosa penis, or to a venous circle surrounding the nipple;[1] but Sir Astley Cooper attributes it simply to an afflux of blood into the capillaries of the part.

Around the nipple is the *areola*, which is of a rosy hue in youth but becomes darker in the progress of life, and the capillary system of which is so delicate as to blush, like the countenance, under similar emotions. The changes, produced on the areola by gestation, have been already described. The skin, at the base of the nipple, and on its surface, is rough, owing to the presence of a number of sebaceous follicles, called by Sir Astley Cooper "tubercles of the areola," which secrete a fluid for the lubrication of the part, and for defending it from the action of the secretions from the mouth of the infant during lactation. Numerous arteries, veins, nerves, and lymphatics,—the anatomical constituents of organic textures in general,—enter into the composition of the mammæ and nipples.

The mammary gland of the male is analogous to that of the female, but much smaller.

The secretion of milk is liable to longer intermissions than any other function of the kind. In the unmarried and chaste female, although the blood, whence milk is formed, may be constantly passing to the breast, no secretion takes place from it. It is only during gestation and some time afterwards, that, as a general rule, the necessary excitation exists to produce it. Yet although largely allied to the generative function,—the mammæ undergoing their chief developement at puberty, and becoming shrivelled in old age,—the secretion may arise independently of impregnation; for it has been witnessed in the unquestioned virgin, the superannuated female, and even in the male sex. The fact as regards the unimpregnated female is mentioned by Hippocrates. M. Baudelocque[2] states, that a young girl at Alençon, eight years old, suckled her brother for the space of a month. Dr. Gordon Smith[3] refers to a manuscript in the collection of Sir Hans Sloane, which gives an account of a woman, at the age of sixty-eight, who had not borne a child for more than twenty years, and nursed her grandchildren, one after another. Professor Hall, of the University of Maryland, related to the author the case of a widow, aged fifty, whom

[1] Prof. Sebastian, Tijdschrift voor Natuurlijke Geschiedenis en Physiologie, door J. Van der Hoeven en W. H. de Vriese, 2de Deel, Bl. i., Amsterdam, 1835.

[2] Art. d'Accouchement, i. 188, Paris, 1822.

[3] Forensic Medicine, p. 484.

he saw giving suck to one of her grandchildren, although she had not had a child of her own for 20 years previously. The secretion of milk was solicited by putting the child to her breast during the night, whilst weaning it. Dr. Francis, of New York, describes the case of a lady, who, 14 years previously, was delivered of a healthy child after a natural labour. "Since that period," he remarks, "her breasts have regularly secreted milk in great abundance, so that, to use her own language, she could at all times easily perform the office of a nurse;" and Dr. Kennedy,[1] of Ashby de la Zouch, has described the case of a woman, who menstruated during lactation; suckled children uninterruptedly through the full course of forty-seven years, and, in her eighty-first year, had a moderate, but regular supply of milk, which was rich and sweet, and did not differ from that yielded by young and healthy mothers. In a note, with which the author was favoured by Dr. Samuel Jackson—formerly of Northumberland County, Pa., now of Philadelphia—a case is described of a lady, certainly above sixty-five years of age, who nursed one of her daughter's twins. She had not borne a child for many years, and was suddenly endowed with a full flow of milk. A lady of Northumberland observed to Dr. Jackson, "that she could not but admire the beautiful fulness and contour of her bosom." Dr. Richard Clarke,[2] of Union Town, South Alabama, has recorded the case of a lady, who had never borne a child, and was requested to take charge of an infant during the illness of its mother. In the course of the night, the infant became restless and fretful, and the lady—to quiet it—put her nipple into its mouth. This was done from time to time, until the milk began to flow. An interesting fact, connected with this case, was, that some time afterwards she conceived, and at the expiration of the usual term was delivered of a fine child. Dr. Clarke refers to other cases, which would appear to show, in another form, the intimate and mysterious sympathy that exists between the mammæ and the uterus. Dr. Green[3] has published the case of a lady, aged 47 years, the mother of four children, who has had abundance of milk for 27 years past. A period of exactly four years and a half occurred between each birth, and the children were permitted to take the breast till they were running about at play. At the time when Dr. Green wrote, she had been nine years a widow, and was obliged to have her breasts drawn daily, the secretion of milk being so copious. In the Samoan group of islands, the mothers often suckle their children until they are six years old; and Captain Wilkes was informed of an instance where a woman gave nourishment to three children of different ages,—the eldest removing the youngest at times by force from the mother's breast.[4] Dr. McWilliam[5] states, that the inhabitants of Bona Vista are accustomed to provide a wet-nurse, in cases of emergency, in any woman who has once borne a child, and is still within the age of child-bearing, by continued fomentation of the mammæ with a decoction of the leaves of jatropha curcas, and by suction of the nipple.

[1] Medico-Chirurgical Review for July, 1832.
[2] American Medical Intelligencer, April 16, 1838, p. 19.
[3] New York Journal of Medicine and Surgery, September, 1844.
[4] Narrative of the United States Exploring Expedition, &c., &c., ii. 138, Philad., 1845.
[5] Report of the Niger Expedition, London Med. Gazette, Jan., 1847.

According to M. Desormeaux,[1] some women are able to continue suckling almost indefinitely, provided the child be put to the breast. It is not uncommon, he says, in France, to see nurses suckle three children in succession, comprising a period probably of from 30 to 36 months; and cases are not rare where women have given suck for four years, and four years and a half. He saw a nurse from Normandy, who had suckled several children successively on the same milk for upwards of five years; and a lady, worthy of all credit, informed him, that she knew a woman who had nursed five children in succession, so that her lactation continued at least seven years. Mr. Erman[2] found, that the Tunguzian women suckle their children for a very long period. In Garmaztakh, he saw a boy, four years old, frequently quieted with the milk, which more properly belonged to his youngest brother. He saw several similar examples amongst the Samoyed women, and learned from a medical gentleman in Tobolsk, that the Ostyok fisherwomen can give milk at all times, "almost like cows."

But these, and cases of a similar nature, of which there are many on record,[3] do not possess the same singularity as those of the function being executed by the male. We have, however, the most unquestionable authority in favour of the occurrence of such cases. A bishop of Cork[4] relates the case of a man who suckled his child after the death of his wife. Humboldt adduces one of a man, thirty-two years of age, who nursed his child for five months on the secretion from his breasts; Captain Franklin[5] gives a similar instance; and Professor Hall, of the University of Maryland, exhibited to his obstetrical class, in the year 1827, a coloured man, fifty-five years of age, who had large, soft, well-formed mammæ; rather more conical than those of the female, and projecting fully seven inches from the chest; with perfect and large nipples. The glandular structure to the touch seemed to be exactly like that of the female. This man, according to Professor Hall, had officiated as wet-nurse for several years in the family of his mistress; and he represented, that the secretion of milk was induced by applying the children, intrusted to his care, to the breasts during the night. When the milk was no longer required, great difficulty was experienced in arresting the secretion. It may be added, that his genital organs were fully developed. In the winter of 1849–50, an athletic man, twenty-two years of age, presented himself at the Clinic of the Jefferson Medical College of Philadelphia, whose left mamma, without any assignable cause, became greatly developed, and secreted milk copiously.[6] It appears, therefore, that the secretion of milk may be caused, independently of a uterus, by soliciting the action of the mammary glands: but that this is a mere exception to the general rule, according to which the secretion is as intermittent as gestation itself.

It has been stated, as one of the signs of pregnancy, that the breasts

[1] Art. Lactation, Dict. de Méd., xxii. 425, Paris, 1838.

[2] Travels in Siberia; translated from the German by W. D. Cooley, ii. 527, London, 1848.

[3] Elliotson's Blumenbach, 4th edit., p. 509, Lond., 1828.

[4] Philos. Trans., xli. 813.

[5] Narrative of a Journey to the Polar Sea, p. 157.

[6] See a letter to the author by C. W. Hornor, in Medical Examiner, August, 1850.

become enlarged and turgid, denoting the aptitude for the formation of milk; and it not unfrequently happens, that, towards the middle and later periods of pregnancy, fluid distils from the nipples. This fluid, however, as well as that which flows from the breasts during the first two or three days after delivery, differs somewhat from milk, containing more serum and butter, and less casein; and is conceived to be more laxative, so as to aid the expulsion of the meconium. The first milk is called *colostrum*, *protogala*, &c., and, in the cow, constitutes the *biestings* or *beastings*. Generally, about the third day after confinement, the mammæ become tumid, hard, and even painful, and the secretion from this time is established, the pain and distension soon disappearing. The circumstances most worthy of note, connected with the colostrum of the cow, in a physiological point of view, are, according to Dr. John Davy[1]—who has carefully inquired into its chemical and other properties—the concentration of nutritive matter in it; the greater facility of its coagulation by rennet compared with older milk, and its greater power of resisting change when exposed to the action of atmospheric air,—qualities which, he thinks, fit it for the first food of the new being. Its ready coagulation may adapt it to the stomach, in which the gastric juice is probably at first in small quantity and feeble; and its power of resisting change, and remaining semi-fluid, may adapt a part of it to the intestines to promote the removal of the meconium; whilst its concentration as nutritive matter may fit it to perform for the calf the same part, that the substance of the egg performs, which enters the intestines during the latter stage of fœtal developement in birds, reptiles and fishes. Whether the first milk of the human female possesses these characters has not been determined.

It is hardly necessary to discuss the views of M. Richerand,[2] who considers the milk to be derived from the lymph; or of others, who derive it from the chyle; of M. Raspail, who is disposed to think, that the mammary glands are in connexion, by media of communication yet unknown, with the mucous surface of the stomach, and that they subtract from the alimentary mass the salts and organizable materials which enter into the composition of the milk; or of M. Girard of Lyons, who gratuitously asserts, that there is in the abdomen an apparatus of vessels,—intermediate between the uterus and mammæ,—which continue inactive, except during gestation, and for some time after delivery; but, in those conditions, are excited to activity.[3] All these notions are hypothetical; and there is no reason for believing, that this secretion differs from others as regards the kind of blood from which it is separated. The separation occurs in the tissue of the gland, and the product is received by the lactiferous ducts, along which it is propelled by the fresh secretion continuously arriving, and by the contractile action of the ducts themselves,—the milk remaining in the ducts and sinuses, until, at times, the mammæ are greatly distended and painful.

The excretion of the milk takes place at intervals. When the lactiferous ducts are sufficiently filled, a degree of distension and uneasiness is felt, which calls for the removal of the contained fluid. At

[1] Transactions of the Medico-Chirurgical Society, 1845.
[2] Nouveaux Elémens de Physiologie, 7ème édit., Paris, 1817.
[3] Adelon, Physiologie de l'Homme, 2de édit., iv. 141, Paris, 1839.

times, the flow occurs spontaneously; but, commonly, only when solicited either by sucking or drawing the breast,—the secretion under such circumstances being very rapid, and the contraction of the galactophorous ducts such as to project the milk through the orifices in a thready stream.

Milk is a highly nitrogenized fluid, composed of water, casein, sugar of milk, certain salts,—as chloride of sodium, phosphate, and acetate of potassa, with a vestige of lactate of iron and earthy phosphate,—and a little lactic acid. Cow's milk consists of cream, and milk properly so called,—the *cream* consisting, according to Berzelius,[1] of butter, 4·5; cheese, 3·5; whey, 92·0;—and the *whey*, of milk and salt, 4·4;—the *milk* containing water, 928·75;—cheese, with a trace of butter, 28·01; sugar of milk, 35·00; chloride of potassium, 1·70; phosphate of potassa, 0·25; lactic acid, acetate of potassa, and lactate of iron, 6·00; and phosphate of lime, 0·30.

M. Raspail[2] defines milk to be an aqueous fluid, holding albumen and oil in solution by means of an alkali, or alkaline salt, which he suggests may be acetate of ammonia,—and, in suspension, an immense number of albuminous and oleaginous globules. The following table exhibits the discrepant results of the investigations of Brisson, Boyssou, Stipriaan Luiscius and Bondt, Schübler, and John, in 1000 parts of the milk of different animals—as given by Burdach.[3]

	Observers.	Specific gravity.	Butter.	Cheese.	Sugar of milk.	Water.	Extract.
Ewe's milk.	Brisson,	10409					
	Boyssou,		38·24	51·26	20·73	886·19	3·45
	Luiscius,	10350	58·12	153·75	41·87	746·25	
	John,		54·68	31·25	39·06	875·00	
Cow's milk.	Brisson,	10324					
	Boyssou,		24·88	39·40	31·33	900·92	3·45
	Luiscius,	10280	26·87	89·37	30·62	853·12	
	Schübler,		24·00	50·47	77·00	848·53	
	John,		23·43	93·75	39·06	843·75	
Goat's milk.	Brisson,	10341					
	Boyssou,		29·95	52·99	20·73	892·85	3·45
	Luiscius,	10360	45·62	91·25	43·75	819·37	
	John,		11·71	105·45	23·43	849·39	
Mare's milk.	Brisson,	10364					
	Boyssou,		0·57	18·43	32·25	938·36	10·36
	Luiscius,	10450	0·00	16·25	87·50	896·25	
	John,		0·00	64·84	35·15	900·00	
Ass's milk.	Brisson,	10355					
	Boyssou,		0·92	19·58	39·97	932·60	6·91
	Luiscius,	10230	0·00	33·12	45·00	921·87	
	John,		0·00	11·71	46·87	941·40	

[1] Medico-Chirurgical Transactions, vol. iii.
[2] Chimie Organique, p. 345, Paris, 1833.
[3] Physiologie als Erfahrungswissenschaft, 2te Auflage, Leipz., 1833.

From this table, an approximation may be made as to the main differences between the milk of those animals; but it is not easy to explain the signal discrepancy amongst observers as to the quantity of the different materials in the milk of the same animal. Much, of course, may be dependent upon the state of the milk at the time of the experiment; but this can scarcely account for the whole discrepancy. From a great number of experiments, MM. Deyeux and Parmentier[1] classed six kinds of milk, which they examined, according to the following table, as regards the relative quantity of the materials they contained.

Casein.	Butter.	Sugar of Milk.	Serum.
Goat. Sheep. Cow.	Sheep. Cow. Goat.	Woman. Ass. Mare.	Ass. Woman. Mare.
Ass. Woman. Mare.	Woman. Ass. Mare.	Cow. Goat. Sheep.	Cow. Goat. Sheep.

The following table has been given more recently.[2] The constituents of the milk of the human family have been added from Clemm.[3] The analysis was made from milk obtained on the twelfth day after delivery.

	Cow.	Goat.	Sheep.	Ass.	Mare.	Woman.
Water, ...	861·0	868·0	856·2	907·0	896·3	905·809
Butter, ...	38·0	33·2	42·0	12·10	traces	33·454
Casein, ...	68·0	40·2	45·0	16·74	16·2	29·111
Sugar of milk and extractive matters,	29·0	52·8	50·0	62·31	87·5	31·537
Fixed salts, .	6·1	5·8	6·8			1·939

Messrs. Vernois and A. Becquerel[4] in 89 observed cases, found the following constituents in human milk.

	Maximum.	Minimum.	Mean.
Density, ...	1·04648	1·02561	1·03267
Water, ...	99·998	83·23	88·91
Solid residuum, ...	14·77	8·33	11·09
Sugar of milk, ...	5·96	2·52	4·36
Casein and extractive, ...	7·09	1·93	3·92
Butter, ...	5·64	0·67	2·67
Salts, ...	0·34	0·06	0·14

Human milk has, therefore, more sugar of milk and less cheesy matter than that of the cow; hence it is sweeter; more liquid; less coagulable; and incapable of being made into cheese. It has also albuminous, oleaginous, and saccharine ingredients combined, so as to

[1] Précis d'Expér., &c. sur les Differentes Espèces de Lait, Strasbourg, an vii., 1790.

[2] Carpenter, Principles of Physiology, 4th Amer. edit., p. 645, Philad., 1850.

[3] Scherer, in Wagner's Handwörterbuch der Physiologie, Art. Milch, 10te Lieferung, S. 464, Braunschweig, 1845. For other analyses, see Simon, Animal Chemistry, Sydenham Soc. edit., ii. 51, London, 1846.

[4] Du Lait, chez la Femme, &c., Paris, 1853. A good analysis of this memoir is given by Dr. Day in the Brit. and For. Med.-Chir. Rev. for July, 1855, p. 218. It treats of the milk of healthy nurses; the influences that may affect it in health; and the changes it experiences in disease.

adapt it admirably for the young as an aliment; and of all the secreted fluids it appears to be most nearly allied to blood in its composition.[1] M. Romanet[2] has affirmed, that the globules in cow's milk are wholly formed of butter, which exists as a pulp, enveloped in a white, translucent, elastic and resistent pellicle; and that the cyst is broken in churning, by which the butter escapes, and the pellicles floating about separately constitute the white particles that give consistence to buttermilk.

When human milk is first drawn it is of a bluer colour than that of the cow. It rather resembles whey, or cow's milk much diluted with water. If allowed to rest, it separates, like the milk of other animals, into cream and milk,—the quantity of the cream being one-fifth to one-third milk. The milky portion, however, appears semitransparent like whey, instead of being white and opaque like that of the cow. During the first days of its remaining at rest, abundance of cream and a little curd are separated, and lactic acid is developed. The specific gravity of human milk was found by Dr. Rees to be 1·0358, and the solid contents 12 per cent. The specific gravity of the cream is 1·021.[3]

The quantitative analysis of the colostrum, after the investigations of Simon, Chevallier and Henry, Stipriaan Luiscius, Boussingault and Le Bel are thus given by Professor Scherer:—[4]

	Woman.	Cow.	Ass.	Goat.	Cow.
	(Simon.)		(Chevallier and Henry.)		(Boussingault and Le Bel.)
Casein (Albumen), .	40·0	170·7	123·0	275·0	151·0
Butter, . . .	50·0	26.0	5·0	52·0	26·0
Sugar of milk, .	70·0		43·0	32·0	36·0
Fixed salts, . .	3·1				3·0
Water, . . .	828·0	803·8	828·4	641·0	784·0
Fixed residue, .	172·0	196·2	171·6	359·0	216·0

Of the 3·1 of fixed salts unalterable by heat, in Simon's analysis, 1·8 part was insoluble in water.

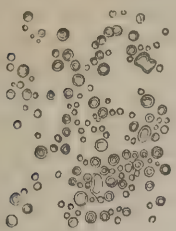
Casein—the nitrogenized constituent of milk—is distinguished from fibrin and albumen by its great solubility, and by not coagulating when heated. This is regarded by Liebig[5] as "the chief constituent of the mother's blood. To convert casein into blood no foreign substance is required; and in the conversion of the mother's blood into casein no elements of the constituents of the blood have been separated."

Examined with the microscope, milk is seen to contain a great number of particles of irregular shape and size, suspended in a somewhat turbid fluid. These vary in size from about the $\frac{1}{12700}$ to the $\frac{1}{3040}$ of an inch, and are called *milk globules.* They consist of oleaginous matter enclosed in an extremely delicate pellicle of albuminous matter. Other globules of a smaller size are also seen, which exhibit a molecular movement in the fluid. They consist of oily matter not inclosed in an envelope. In the colostrum or first secreted milk, large yellow granulated corpuscles—*colostrum corpuscles*—are seen, which appear to

[1] Dr. G. O. Rees, Art. Milk, Cyclop. of Anat. and Physiol., Nov., 1841.
[2] Comptes Rendus, Avril, 1842.
[3] Sir Astley Cooper, on the Anatomy of the Breast, Amer. edit., p. 83, Philad., 1845.
[4] Op. cit., S. 451.
[5] Animal Chemistry, Amer. edit., p. 51, Cambridge, 1842.

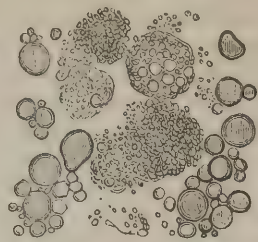
be formed of a number of small grains in a state of aggregation. They are chiefly of a fatty nature, being, for the most part, soluble in ether;

Fig. 459.



Milk Globules.

Fig. 460.



Colostrum Corpuscles.

but traces of an adhesive matter, probably mucus, are then seen holding the particles together. Epithelial scales are also perceptible in milk.

The quantity and character of the milk differ according to the quantity and character of the food,—a circumstance, which was one of the greatest causes for the belief, that the lymphatics or chyliferous vessels convey to the mammæ the materials for the secretion. The milk is, however, situate in this respect like the urine, which varies in quantity and quality according to the amount and kind of solid or liquid food taken. The milk is more abundant, thicker, and less acid, if the female lives on animal food; and possesses the opposite qualities when vegetable diet is used. It is apt, also, to be impregnated with heterogeneous matters, taken up from the digestive canal. The milk and butter of cows indicate unequivocally the character of their pasturage, especially if they have fed on turnip, wild onion, &c. Medicine, given to the mother, may in this way act upon the infant. Serious—almost fatal—narcotism was induced in the infant of a professional friend of the author, by a dose of morphia administered to his wife.

It would seem, that occasionally the secretion of the two glands differs. A case has been related in which the milk of the right breast had a distinctly salt taste, whilst that of the opposite breast was of the ordinary sweetness. A difference also is at times observed in the number and size of the globules of the milk obtained from the two breasts. M. Devergie[1] has found by examination with the microscope, that the milk of women differs not only in respect to the size of the globules, but to the number of these,—a high or low amount of globules indicating richness or poorness of the milk generally. Of 100 nurses, 17 had the large globuled variety; 22 the small globuled; and 61 the medium size.

The quantity of milk secreted is not always in proportion to the bulk of the mammæ: a female whose bosom is of middle size often secretes more than one in whom it is much more developed;—the greater size being usually owing to the larger quantity of adipous tissue surrounding the mammary gland, which tissue is nowise concerned in the function. The ordinary quantity of milk that can be squeezed from either

[1] Mémoires de l'Académie Royale de Médecine, tom. x., Paris, 1843.

breast at any one time, and which must consequently have been contained in its tubes and reservoirs, is about two fluidounces. The secretion usually continues until the period when the organs of mastication of the infant have acquired the necessary developement for the digestion of solid food; and it generally ceases during the second year. For a great part, or the whole of this time, the catamenia are suspended; and if both the secretions, mammary and menstrual, go on together, the former is usually impoverished, and in small quantity. This, at least, is the general opinion. Some, however, think, that no general rule can be established on the subject; and that the condition of the child's health ought to be the only guide in regard to weaning, after the recurrence of the catamenia. M. Gendrin would on no account permit a woman to continue nursing after they had returned. The subject has been investigated by M. Raciborski,[1] who laid the results before the *Académie Royale de Médecine*, of Paris, in May, 1843. His inferences are,—that, contrary to generally received opinion, the milk of nurses who menstruate during suckling does not differ sensibly, in physical, chemical, or microscopic characters, from that of nurses whose catamenia are suspended; that the only difference, which can be detected between the two kinds of milk, is, that in most cases the milk of menstruating nurses contains less cream during the menstrual periods than in the intervals, which accounts for the bluish appearance occasionally presented by such milk;—and that a nurse should never be rejected merely because she menstruates.

Whilst lactation continues, the female is less likely to conceive; hence the importance,—were there not even more weighty reasons,—of the mother's suckling her own child in order to prevent the too rapid succession of children. From observations made at the Manchester Lying-in Hospital on one hundred and sixty married women, Mr. Roberton[2] concludes, that in seven out of eight women, who suckle for as long a period as the working classes in England are in the habit of doing—about fifteen and a half months on the average—there will be an interval of fifteen months between parturition and the commencement of the subsequent pregnancy; and that, in a majority of instances, when suckling is prolonged to even nineteen or twenty months, pregnancy does not take place till after weaning. In a work on the law of population and subsistence, Dr. Loudon[3] lays down the theory, that the laws of nature require lactation to be prolonged for three years; and he expresses an opinion, that the antagonism between the uterus and mammæ is so great as usually to prevent conception in women who have infants at the breast. The opinion does not agree, however, with the facts arrived at by Dr. Roberton, and it is still more opposed to those of Dr. Laycock,[4] who states that 135 married women afforded 209 pregnancies during 766 lactations, or 1 pregnancy in 3·66 lactations, or 27 per cent. The 209 pregnancies occurred in 76 females:—that is, 56 per cent. became pregnant whilst suckling; but in 30 of these, pregnancy occurred only once. If the thirty be deducted, there

[1] Dublin Medical Press, Aug. 2d, 1843.

[2] Edinb. Med. and Surg. Journal, Jan., 1837.

[3] Solution du Problème de la Population, &c., Paris, 1842; cited by Dr. West, in Brit. and For. Med. Rev., April, 1844, p. 541.

[4] Dublin Medical Press, Oct. 26, 1842.

remain 46 or 33·9 per cent., or nearly 1 in 3, who became pregnant on more than one occasion whilst suckling; and 19 of these, or 1 in 7 had always—after their first pregnancy—conceived whilst suckling.

When menstruation recurs during suckling, it is an evidence that the womb has again the organic activity which befits it for impregnation.

Vicarious secretion of milk is sometimes—yet rarely—met with. An interesting case of expectoration of a milky fluid has been recorded by Dr. S. Wier Mitchell,[1] of Philadelphia; in which the microscope exhibited very perfect milk globules, mingled with compound granular cells, mucous corpuscles, and epithelial scales or lamellæ.

CHAPTER II.

FŒTAL EXISTENCE.—EMBRYOLOGY.

WHILST the uterine alterations, which have been pointed out in the last chapter, are taking place, the ovum is undergoing a succession of changes, and the new being is passing through the different phases of intra-uterine existence. The history of these, in the early period, is extremely obscure, owing to the difficult nature of the investigation; and on many deeply interesting points we are compelled to remain in doubt. It is a subject, which has engaged the attention of physiologists of all ages; but it is chiefly to those of more modern times—as Hunter, Cuvier, Dutrochet, Pander, Rolando, Sir Everard Home and Mr. Bauer, Prévost and Dumas, Von Baer, Kuhlemann, Döllinger, Oken, Purkinje, Rathke, C. F. Wolff, Breschet, Burdach, Reichert, Carus, Krause, Seiler, Bojanus, Meckel, E. H. Weber, Bernhardt, Valentin, Coste, Owen, Sharpey, Velpeau, Flourens, Allen Thomson, T. W. Jones, Bischoff, Schwann and Schleiden, J. Müller, Pouchet, Wagner and Martin Barry,—the last two of whom received, about the same time, medals for their researches, the former from the Institute of France; the latter from the Royal Society of London,—that we are indebted for our more accurate and precise information.

1. ANATOMY AND HISTOLOGY OF THE FŒTUS.

a. *Fœtal Developement.*

As the developement of the mammalia greatly resembles that of birds, the histogeny of the impregnated ovum, at the earliest periods, was, until of late years, chiefly studied in the latter; and there can be no doubt—as Wagner[2] has remarked,—that carefully conducted researches on the ovum of these animals are much better calculated to throw light on the developement of the human embryo than any amount of necessarily unconnected observations of human ova aborted at an early period; and, in the majority of cases perhaps, morbid. "Unques-

[1] American Journal of the Medical Sciences, July, 1855, p. 83. A similar case is cited in the Brit. and For. Med. Rev., for Jan., 1840, from Bulletino delle Scienze Mediche, April, 1839.

[2] Elements of Physiology, by R. Willis, p. 80, Lond., 1841.

tionably," observes Valentin,[1] "the class of birds is the centre around which all observations on developement arrange themselves, and this, not so much on account of any grounds intrinsic to this class, as by reason of extrinsic circumstances, which are completely under our control. In no other class of animals do we possess the same facilities of procuring embryos in the various stages of their progress. Nowhere can we multiply and repeat our inquiries to the same extent as here. It was on this account that Fabricius ab Aquapendente began his investigations with the brooded egg, and that Harvey and Malpighi followed in the same course. It was on the egg that Wolff made his important discoveries in regard to the formation of the intestinal canal, of the blood, of the extremities, and of the kidneys; and it was by the study of the embryo of the common fowl, that Döllinger and his school, in our own day, were enabled to give a permanent foundation to the history of developement as a science. The bird must, therefore, and on these grounds, be made the starting point for all future inquiries, the norma and basis to which insulated facts in the developement of mammalia and man must be referred." It has been well remarked, too, by Wagner,[2] that whoever would work out a knowledge of the developement of animals generally for himself must begin with the study of the chick, were it only for the reason, that we possess the best descriptive works upon this portion of the subject. The early processes of developement are, indeed, the same in all animals. "The embryos of different animals resemble each other more strongly in proportion as we examine them at an early period. We have already stated, that during almost the whole period of embryonic life, the young fish and the young frog scarcely differ at all; so it is also with the young snake, compared with the embryo bird. The embryo of the crab, again, is scarcely to be distinguished from that of the insect; and if we go still farther back in the history of developement, we come to a period when no appreciable difference whatever is to be discovered between the embryos of the various departments. The embryo of the snail, when the germ begins to show itself, is nearly the same as that of a fish or a crab. All that can be predicted at this period is, that the germ, which is unfolding itself, will become an animal: the class and group are not yet indicated."[3]

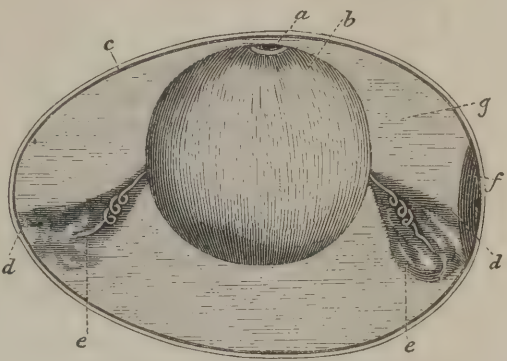
The egg of a bird—of a hen, for example—consists of two descriptions of parts,—the one comprising those that are but little concerned in the developement of the new being;—the other those that remain after the chick is hatched,—as the shell and the shell membrane which lines it; and those that undergo changes along with the chick, and cooperate in its formation, as the white, the yolk, and the *cicatricula macula*, *tread* or *gelatinous molecule* as it was formerly termed—which includes the *germinal vesicle* or *Purkinjean vesicle*, and the *germinal* or *germ spot* of later observers.

When the ovule quits the ovary, it consists only of the yolk and its investing membrane:—with the germinal vesicle and germinal spot. (See Figs. 425 and 426.) The yolk serves the same purpose for the

[1] Handbuch der Entwickelungsgeschichte, Vorrede s. x.
[2] Op. cit.
[3] Agassiz and Gould, Principles of Zoology, part 1, page 123, Boston, 1848.

animal as the amylaceous and oily matter in the seed serves for the plant. It is the nutriment on which the embryo subsists, until it is capable of obtaining it in another manner. On this yolk is the cicatricula, consisting, as has been said, of a nucleated cell, of which the germinal spot is the *nucleus*,—the germinal vesicle the *cell*. In its passage through the oviduct, the ovule receives the albumen or white of egg, the purpose of which is to serve as nutriment; for it is gradually taken up as the yolk is exhausted. This is deposited upon the surface of the ovule; and from the bloodvessels of the lining of the oviduct are thrown out the materials that go to the formation of the *shell membrane* — *membrana testæ*—as well as of the shell itself. This membrane separates into two layers at the larger end of the egg; and, enclosed between them, is the *folliculus aëris* or *air chamber*, containing a bubble of air, and inservient to the respiration of the embryo. The yolk floats within the albumen, and being the lighter of the two tends to rise towards the upper portion; but is retained nearly in the same place by two cords formed of very viscid albumen, which connect the yolk bag with the lining membrane at the two ends of the shell, and are called *chalazæ* or *poles*.

Fig. 461.



Section of Bird's Egg.

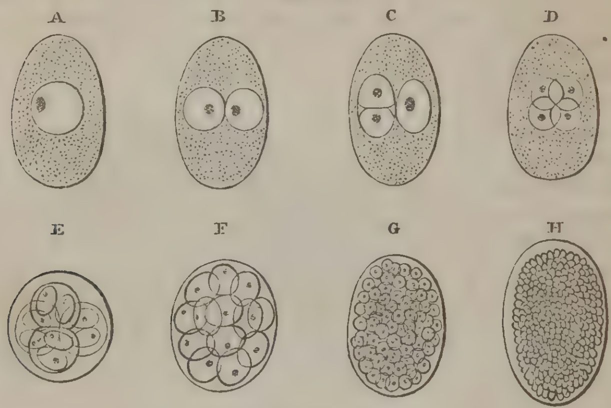
a. Cicatricula. *b.* Yolk. *c.* Shell Membrane. *d.* Attachment of chalazæ. *e.* Chalazæ. *f.* Air-Chamber. *g.* Albumen.

The ovum of the mammalia is strikingly analogous to this. When it leaves the ovary, it consists of the *yolk* or *vitellus*, contained in its yolk-bag, and of the germinal vesicle and germinal spot. At times, however, the germinal vesicle disappears before the ovum leaves the ovary; but at others not until it has entered the Fallopian tube or oviduct; and it is only in its passage through the tube, that it receives,—by means of nucleated cells, thrown out from the lining membrane,—the *chorion*, which is thus analogous to the albumen or white, the shell membrane and shell of the bird.

In tracing the early developement of the ova of mammiferous animals, difficulty has existed; and hence attention has been chiefly paid to the lower animals, in which there is every reason to believe that similar phenomena occur. Prior to impregnation, the germinal vesicle and germinal spot are visible in the ovum; but after fecundation, the germinal vesicle disappears, and in its place is seen a nucleated cell (Fig. 462, A), which appears to be a new formation. A process of duplication now takes place, which is depicted by Kölliker and Bagge, as seen by them in the ova of certain parasitic worms, in which it presents itself in its least complex form; and, owing to the transparency of the objects, can be the more readily traced. The nucleus of the

first nucleated embryonic cell is divided, and each new nucleus is soon succeeded by two other cells; these by four; and these again by eight, as illustrated in Fig. 462; this duplication continuing, and the cells being progressively smaller, until ultimately a large mass of cells results, which assumes the form of the embryo. (H, Fig. 462.) Along with these changes, the yolk is experiencing considerable modi-

Fig. 462.



Duplication of Cells.

A, B, C, D. Successive stages of the ovum of ascaris dentata, showing duplication of cells. E, F, G, H. Ovum of cucullanus elegans, showing the advance of the process.

fication. In some entozoa, as in those described in Fig. 462, the embryonic portion is embedded in the interior of the yolk, and as the cells multiply they draw into them the nutrient matter that surrounds them, until the whole yolk is absorbed, and the original yolk-bag is filled with a mulberry-like mass of cells; but the more common method is for each of the cells formed by the cleaving of the embryonic vesicle to draw around it a certain portion of the yolk as in Fig. 463.[1]

Fig. 463.

Cleaving of the Yolk after Fecundation.

A, B, C. Ovum of ascaris nigrovenosa. D and E. That of ascaris acuminata.

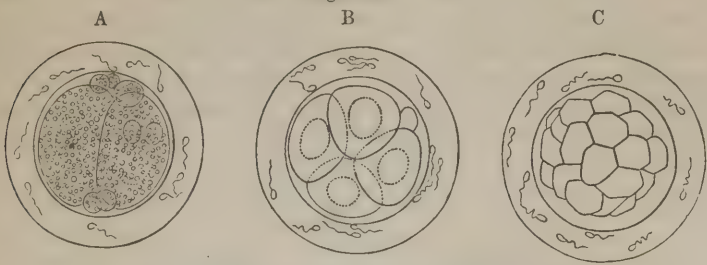
The same kind of metamorphosis, or cleaving of the yolk, occurs in the mammalia; prior to this, however, certain changes have been observed by Bischoff.[2] The cells of the membrana granulosa, that are in

[1] Baly and Kirkes, Recent Advances in the Physiology of Motion, the Senses, Generation, and Developement, p. 66. London, 1848.

[2] Entwickelungsgeschichte des Hunde-eies, p. 41; and Baly and Kirkes, p. 64.

immediate contact with the ovum, undergo a peculiar change when it is about to leave the ovary—becoming club-shaped, their pointed ex-

Fig. 464.

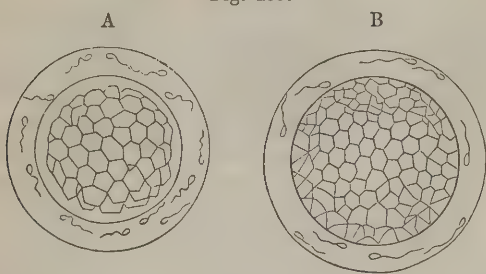


Progressive stages in the Segmentation of the Yolk of the Mammalian Ovum.

A. Its first division into two halves. B. Subdivision of each half into two. C. Further subdivision, producing numerous segments.

tremities being attached to the zona pellucida so as to give to the ovum a stellate appearance; but when the ovum has entered the Fallopian

Fig. 465.

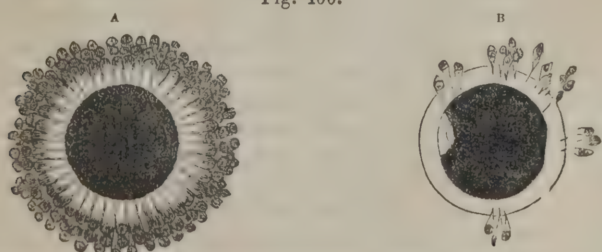


Later stage in the Segmentation of the Yolk of the Mammalian Ovum.

At A is shown the "mulberry mass" formed by the minute subdivision of the vitelline spheres. At B a further increase has brought its surfaces into contact with the vitelline membrane, against which the spherules are flattened.

tube, they lose this shape and become round; and in this form they continue, in the bitch, to invest the ovum throughout the whole tract

Fig. 466.



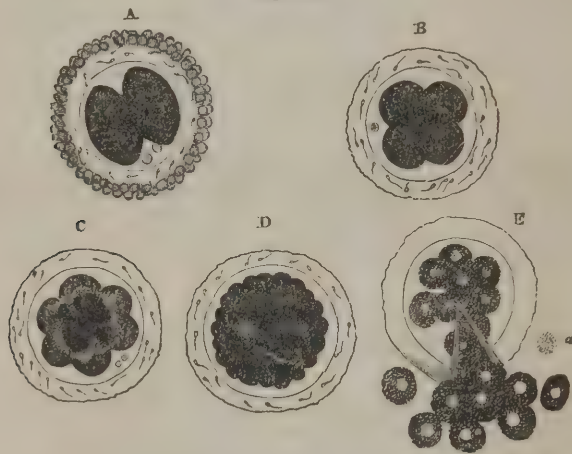
Membrana Granulosa of an Ovum from the Ovary.

A. An ovarian ovum from a bitch in heat, exhibiting the elongated form and stellate arrangement of the cells of the discus proligerus or membrana granulosa around the zona pellucida. B. The same ovum after the removal of most of the club-shaped cells.

of the Fallopian tube, and are no longer seen when it reaches the uterus; but in the rabbit they disappear at the commencement of the tube, and it is observed that the yolk no longer completely fills the zona pellucida; a clear space being left between them.

In its progress through the tube, besides the reception of the chorion as an investing membrane, no change of structure is seen in the ovum, excepting that the zona pellucida is thicker; but Bischoff,[1] observed in the rabbit, that regular energetic rotatory movements were executed by the yolk within the zona pellucida, which he ascribed to the motions of vibratile cilia on the surface of the yolk.

Fig. 467.



Ova from the Fallopian Tube and Uterus.

A. Ovum of a bitch, from the Fallopian tube, half an inch from its opening into the uterus, showing the zona pellucida with adherent spermatozoids, the yolk divided into its first two segments, and two small granules or vesicles contained with the yolk in the cavity of the zona. B. Ovum of a bitch from the lower extremity of the Fallopian tube: the cells of the tunica granulosa have disappeared: the yolk is divided into four segments. C. Ovum of a bitch from the lower extremity of the Fallopian tube, in a later stage of the division of the yolk. D. An ovum from the uterus; it is larger, the zona thicker, and the segments of the yolk are very numerous. E. Ovum from the lower extremity of the Fallopian tube burst by compression; the segments of the yolk have partly escaped, and in each of them a bright spot or vesicle is visible.

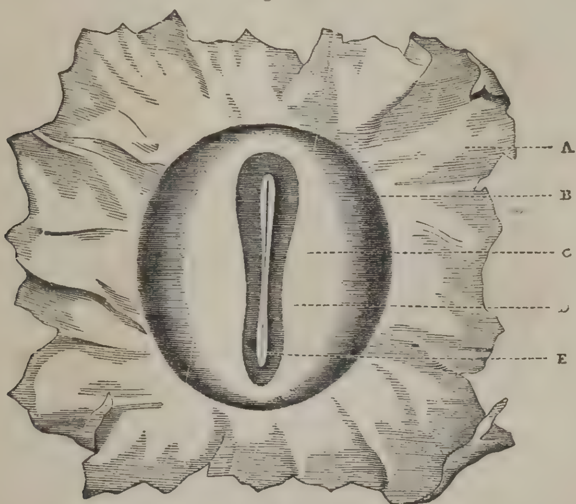
It is in the second half of the Fallopian tube, that the cleaving of the yolk begins; which is now resolved into a number of smaller spheroidal masses, under the same process of duplication that has been witnessed in the entozoa. Each mass contains a transparent vesicle like an oil globule, in which no nucleus has been detected; yet the vesicles would appear to possess plastic powers like the primordial embryonic vesicle from which they descended.

At the time when the mammalian ovum has reached the uterus, the cleaving process has ceased; but soon afterwards important changes take place. Each of the globular segments of the yolk becomes surrounded by a membrane, which forms it into a cell; and when the peripheral cells, which are first formed, are fully developed, they arrange themselves at the surface of the yolk into a kind of membrane, and

[1] Müller's Archiv., S. 14, Jahrgang, 1841; and Elements of Physiology, by Baly, p. 1564, Lond., 1838.

assume a pentagonal or hexagonal shape from pressing on each other, so as to resemble pavement epithelium. As the globular masses of the interior are gradually formed into cells, they pass to the surface; increase the thickness of the membrane formed by the peripheral layer of cells, whilst the central part of the yolk is filled only with a clear fluid. By this means, the yolk is converted into a kind of secondary vesicle, situated within the zona pellucida, which Bischoff calls the *blastodermic vesicle,—vesicula blastodermica*, the *blastoderma* or *germinal membrane*, because in it is first observed the *germ* or earliest trace of the new being. Soon after its formation, the membrane presents, at some point on its surface, an opaque roundish spot, caused by an accu-

Fig. 468.



Portion of the Germinal Membrane of a Bitch's Ovum, with the Area Pellucida and Rudiments of the Embryo. Magnified ten diameters.

A. Germinal membrane. B. Area vasculosa. C. Area pellucida. D. Laminæ dorsales. E. Primitive groove, bounded laterally by the pale pellucid substance of which the central nervous system is composed.

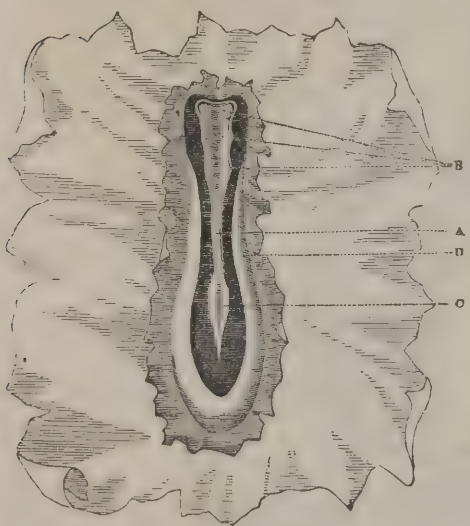
mulation of cells and nuclei of less transparency than elsewhere; and it is here—in the *area germinativa*, as it is called—that the embryo first appears. The germinal membrane increases in thickness by the formation of new cells, and is divisible into two layers, which are, at first most distinct at the area germinativa; but the separation soon extends, and affects nearly the whole germinal membrane. The outer layer of these is called the *serous layer* and also the *animal layer*, because from it are formed the organs of animal life:—the nervous system, bones, muscles, &c.; whilst the latter or inner layer is called the *mucous* or *vegetative layer*, because from it are formed the vegetative or nutritive organs.

The area germinativa has, at first, a rounded form, which it soon loses, becoming first oval, and then pyriform; and whilst this change is taking place, a clear space—*area pellucida*—is seen in its centre; this is bounded externally by a more opaque circle, which subsequently

becomes the *area* or *area vasculosa*, so called because bloodvessels are there first developed. In the formation of both these areas, the two layers participate.

The first appearance of the embryo is seen in the serous layer and in the centre of the area pellucida. It consists of a shallow groove—*primitive groove, trace or streak*—having on each side two oval masses—*laminæ dorsales*—the form of which changes with that of the area pellucida; being, at first, oval, then pyriform, and at length shaped like a guitar. At the same time, they become more and more raised, and the tops of the elevations approach each other, until they ultimately convert the groove into a tube, which is the seat of the future great central organs of the nervous system—the brain and spinal marrow. At the same time, on a line parallel with the primitive groove, a row of cells is seen, which are the rudiments of the future vertebral column;—this is termed the *chorda dorsalis*.

Fig. 469.



Portion of the Germinal Membrane, with Rudiments of the Embryo from the Ovum of a Bitch.

The primitive groove, A, is not yet closed, and at its upper or cephalic end presents three dilatations, B, which correspond to the three divisions or vesicles of the brain. At its lower extremity the groove presents a lancet-shaped dilatation (sinus rhomboidalis) C. The margins of the groove consist of clear pellucid nerve-substance. Along the bottom of the groove is observed a faint streak, which is probably the chorda dorsalis. D. Vertebral plates.

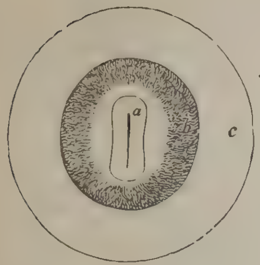
Whilst the dorsal laminæ are approaching to close the primitive groove, thickened prolongations of the serous layer are given off from the lower margin of each. These—called ventral or visceral laminæ, *laminæ ventrales* seu *viscerales*—at first, proceed on the same plane with the germinal membrane, but they gradually bend downward and inwards, towards the cavity of the yolk, where they unite, and form the anterior wall of the trunk; and whilst these changes are supervening, an accumulation of cells is taking place between the serous and the mucous layer of the germinal membrane, which arrange themselves into a distinct layer—the *vascular*—in which the first vessels of the embryo are developed.

Such are the phenomena presented by the embryo chick; but, according to Dr. Martin Barry,[1] there does not occur in the mammiferous ovum any such phenomenon as the splitting of a germinal membrane into the "so called *serous*, *vascular*, and *mucous laminæ*. Nor is there any structure entitled to be denominated a *germinal membrane*; for it

[1] Philosophical Transactions for 1838, 1839 and 1840, and Wagner's Elements of Physiology, p. 153 (note), London, 1841.

is not a previously existing membrane, which originates the germ; but it is the previously existing germ, which, by means of a hollow process,

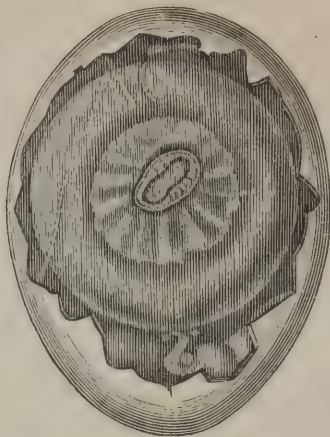
Fig. 470.



Vascular Area in the Chick thirty-six hours after Incubation.

a. Yolk. *b*. Fiddle-shaped pellucid area, in the middle of which is the embryo. In the vascular area, *c*, *c*, the insulæ sanguinis or blood islets begin to appear.

Fig. 471.

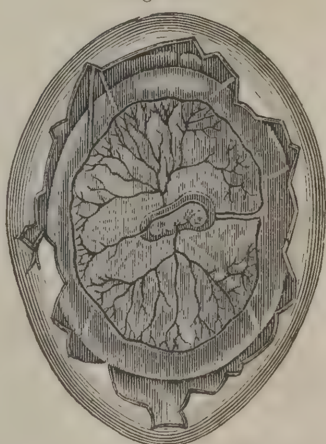


Egg thirty-six hours after Incubation.

originates the structure having the appearance of a membrane." This we have no doubt is the fact as regards the relation of the germ to the germinal membrane, yet the phenomena may present themselves in the manner above described.

When the vascular layer is formed, blood dots or islets—*insulæ sanguinis*—appear at the circumference of the vascular area, which gradually unite so as to form vessels filled with blood, which have a retiform appearance and circular shape; hence the name *circulus venosus* and *vena* seu *sinus terminalis* given to the *figura venosa.* The vascular area gradually extends itself over the whole surface of the membrane that contains the yolk; as is well seen in the accompanying figures of the chick at different stages of incubation.

Fig. 472.

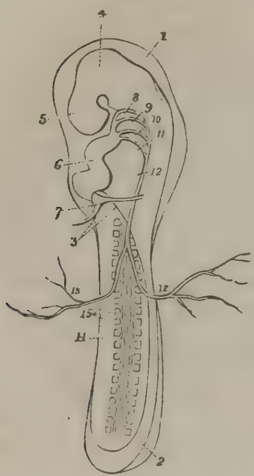


Egg opened three days after Incubation.

From this network in the area vasculosa, vessels extend into the area pellucida, and join the rudimental heart, which has, at first, the form of a long slightly curved tube, prolonged inferiorly into two venous trunks, and superiorly into three or more aortic arches on each side. These arches unite beneath the vertebral column to form the aorta (Fig. 473). In

the primitive state of the circulation, the descending aorta divides into a right and a left branch (Fig. 474) which pass to the germinal membrane,

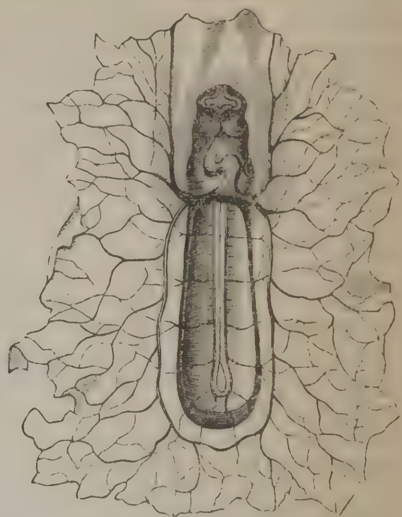
Fig. 473.



Embryo of the Chick at the commencement of the third day, as seen from the abdominal aspect.

4. Prominence of the corpora quadrigemina or optic lobes of the brain. 5. The anterior cerebral mass or hemispheres. 6. The heart. 7. Entrance of the great venous trunks in the atrium cordis or auricle. 8, 9, 10 and 11. The four aortic arches. 12. The descending aorta. 13. The arteries of the germinal membrane. 14. The dorsal lamina, rendered slightly wavy by the action of water. 15. The rudiments of the vertebræ.

Fig. 474.

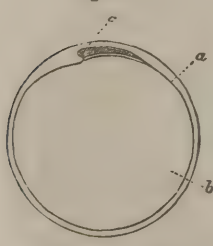


Embryo from a Bitch at the 23d or 24th day. Magnified ten diameters.

It shows the net-work of bloodvessels in the vascular lamina of the germinal membrane and the trunks of the omphalo-mesenteric veins entering the lower part of the S-shaped heart. The first part of the aorta is also seen.

and are termed *arteriæ omphalo-mesentericæ*, where they ramify until they reach the *circulus venosus*, which—as has been seen—surrounds the area vasculosa; from this, the blood is conveyed back by the *venæ omphalo-mesentericæ*, which issue from the area vasculosa at points corresponding to the anterior and posterior extremities of the embryo (Fig. 474). The sinus terminalis ultimately disappears, and the whole yolk-sac becomes covered with bloodvessels. The same plastic material which formed the different bloodvessels is concerned in the formation of the blood corpuscles; and the essential use of the bloodvessels themselves is, doubtless, to absorb the nutritious matter of the yolk, and convey it to the embryo for histogenic purposes.

Fig. 475.



Plan of Early Uterine Ovum.

Within the external ring, or zona pellucida, are the serous lamina, *a*; the yolk, *b*; the incipient embryo, *c*.

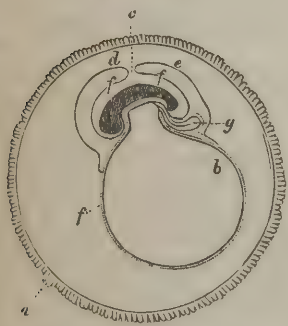
At a very early period, the incipient embryo lies, as it does subsequently, with its ventral surface on the yolk sac; and soon, in the mammalia, a constriction takes place in the fold of the germinal membrane in

which the parietes of the abdomen are formed; and from this time the yolk sac becomes the *vesicula umbilicalis* or umbilical vesicle. The constricted portion, which remains open for a time, is the *vitelline* or *omphalo-mesenteric duct*, *ductus vitellarius*, *ductus vitello-intestinalis* seu *apophysis*, and the omphalo-mesenteric vessels are still perceptible. Through them, indeed, as at an earlier period, the vitelline matter is conveyed to the embryo. It is affirmed, however, that the vessels are not in immediate contact with the yolk,—a layer of nucleated vitelline cells intervening, which communicate a yellow colour to the vessels beneath, and hence Haller called those vessels *vasa lutea*. It would not seem, however, that cell agency is necessary in this case, for adipous matter readily enters the vessels by imbibition.

The walls of the umbilical vesicle or yolk sac are formed of the several layers of the germinal membrane, the mucous and vascular layers of which become much developed; and its vessels—the omphalo-mesenteric, consisting of an artery and two veins—communicate with the abdomen at the umbilicus by the vitelline duct, which, again, communicates with the cavity of the rudimental intestine of the embryo which had been pinched off from the yolk bag; and it was at one time supposed that the nutrient matter of the yolk passed at once through the duct into the rudimental digestive cavity; but it is now generally believed that it is taken up by the vessels in the manner already described.

Whilst the umbilical vesicle is experiencing these developements, another vesicle is seen to project gradually from the caudal extremity of the embryo, which is termed the *allantois* or *allantoid vesicle;* and has been supposed by some histologists to be an offset, as it were, from

Fig. 476.



The Amnion in process of formation, by the arching over of the Serous Lamina.

a. The chorion. *b*. The yolk bag, surrounded by serous and vascular laminæ. *c*. The embryo. *d*, *e*, and *f*. External and internal folds of the serous layer, forming the amnion. *g*. Incipient allantois.

Fig. 477.

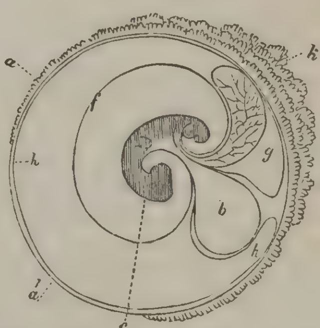


Diagram representing a Human Ovum in the second month.

a, 1. Smooth portion of chorion. *a*, 2. Villous portion of chorion *k*, *k*. Elongated villi beginning to collect into placenta. *b*. Yolk sac, or umbilical vesicle. *c*. Embryo. *f*. Amnion (inner layer). *g*. Allantois. *h*. Outer layer of amnion, coalescing with chorion.

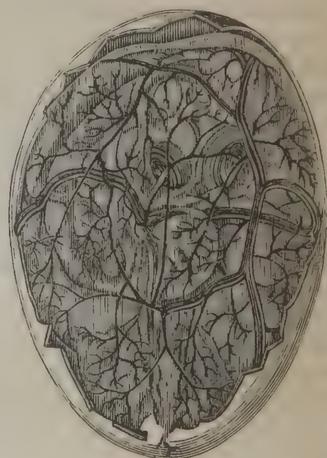
the intestinal canal; but, according to Bischoff, it is certainly not so in the mammalia, in which it never attains any great size; but in birds it extends itself around the whole of the yolk sac, between it and the

shell membrane. The figures 476, 477, 478, 479 exhibit it at different stages in the egg of the hen; and in the human ovum. As the allantois is developed, its parietes become very vascular, and contain the ramifications of the subsequent umbilical arteries and umbilical vein. Wherever it is met with, it would appear to be a temporary organ of respiration; destined to bring the vessels of the embryo chick in relation with the external air; and in the mammiferous animal to convey the vessels of the embryo to and from the chorion. As the visceral laminæ close in the abdominal cavity, the allantois is divided at the umbilicus into two portions; the larger proceeding with the umbilical

Fig. 478.

Egg five days after Incubation.

Fig. 479.



Egg ten days after Incubation.

vessels to the chorion,—the smaller being retained in the abdomen, and converted into the urinary bladder. The two portions are connected by the *urachus.*

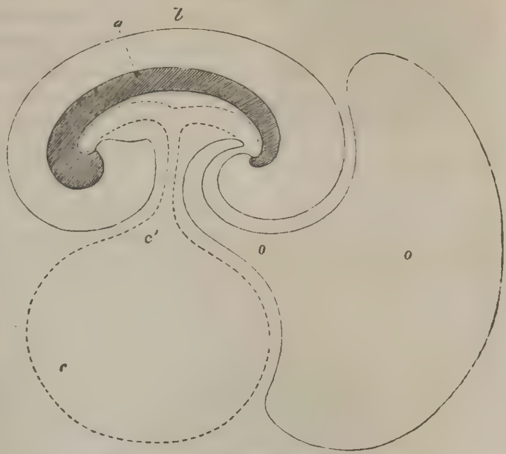
But whilst the umbilical vesicle is undergoing its incipient formation, by the constriction of that portion of the yolk sac which is in relation with the future umbilicus of the embryo, an important change is taking place in the serous layer of the germinal membrane, the cephalic, caudal and lateral edges of which rise up in two folds, and extend over the body of the embryo from its abdominal towards its dorsal aspect, where they at length meet, and enclose the embryo in a double envelope, one layer of which—the inner—forms the sac of the *amnion;* the other lines the internal surface of the chorion.

Its mode of developement is seen in Figs. 476, 477 and 480.

The amnion is continuous with the integument of the embryo; and the part at which the reflections take place to form it is the *umbilicus;* this is well illustrated in the marginal figure. When the ovum has reached the interior of the uterus it is surrounded by the chorion, which it received in its passage along the Fallopian tube: the villi or fœtal processes on its outer surface come in relation with the enlarged

tubular glands of the uterus, and thus the new being derives its early intra-uterine nutriment. Gradually, however, bloodvessels are developed in the villi, which form a junction with those of the allantois—the umbilical vessels; and in this way an indirect vascular communication is established with the uterus, which is concentrated in the part corresponding to the placenta. The mode in which this connection is formed will be described when the dependencies of the fœtus and its physiology are more intimately investigated.

Fig. 480.



The Umbilical Vesicle, Allantois, &c.

a. Represents the dorsal structures of the embryo. *b*. The amnion. *c*. The yolk-sac or umbilical vesicle. *c′*. The vitelline duct or pedicle of the umbilical vesicle. *o*. The allantois; and *o′*. The Urachus.

From the difficulty of appreciating the exact age of any ovum or its contained embryo, it is impracticable to assign precise weights or measurements, or, indeed, any special developement to the different periods of intra-uterine existence. The discordance amongst observers is, indeed, extreme; and the following observations can only be regarded as approximations.

The human ovum does not generally reach the uterus until about ten or twelve days after conception, or after its discharge from the ovary. Reference has already been made to the disputed case by Sir Everard Home, in which, on the seventh or eighth day after conception, the future situations of the brain and spinal marrow were said to have been recognizable by a powerful instrument.[1] On the thirteenth or fourteenth day, according to M. Maygrier, it is perceptible in the uterus, and of about the size of a pea, containing a turbid fluid, in the midst of which an opaque point is suspended. Fig. 481 represents an ovum, which is figured by M. Velpeau, and could not have been more than fourteen days old, unless the midwife, who gave it him, and who was herself the subject of the miscarriage, deceived him; and she appeared to have had no reason for so doing. Good descriptions and representations of the human ovum within the first month from conception are, however, as Wagner[2] has remarked, very rare; and many of the accounts apper-

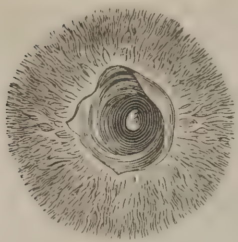
Fig. 481.

Ovum fourteen days old.

[1] Dr. Myddleton Michel, of South Carolina, has described a very early human ovum observed by him; and has referred to various others recorded by different observers, in the American Journal of the Medical Sciences for Oct., 1847, p. 330.

[2] Elements of Physiology, translated by R. Willis, p. 161, Lond., 1841.

Fig. 482.

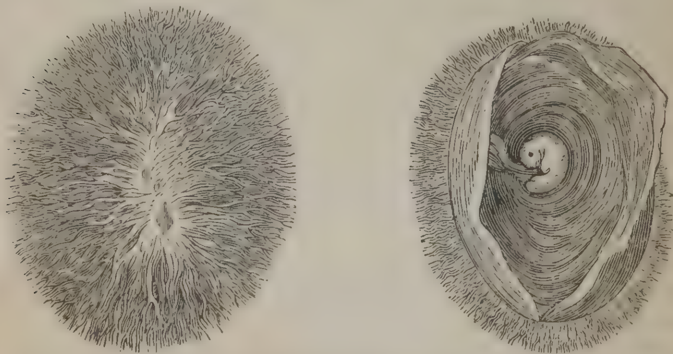


Ovum and Embryo fifteen days old.

tain to diseased ova, or to monstrous or distorted embryos thrown off by abortion. Its *weight* at this period, has been valued at about a grain;—*length* one-twelfth of an inch.

On the twenty-first day, the embryo appears under the shape of a large ant, according to Aristotle; of a grain of lettuce; a grain of barley, according to Burton; of the malleus of the ear, according to Baudelocque; or is one-tenth of an inch long, according to Pockels. At this period, its different parts have a little more consistence; and those that have afterwards to form bone assume the cartilaginous condition. On the thirtieth day, some feeble signs of the principal organs and of the situation of the upper limbs are visible; *length* four or five lines.

Fig. 483.



Ovum and Embryo twenty-one days old.

About the forty-fifth day, the shape of the child is determinate; and it now, in the language of some anatomists, ceases to be *embryo*, and becomes *fœtus*. According to others, it is not entitled to the latter name until after the beginning of the fourth month.

Fig. 484. Fig. 485.

Fœtus at forty-five days. Fœtus at two months.

The limbs resemble tubercles, or the shoots of vegetables; the body lengthens, but preserves its oval shape,—the head bearing a considerable proportion to the rest of the body. The base of the trunk is pointed and elongated. Blackish points, or lines, indicate the presence of the eyes, mouth, and nose; and similar parallel points correspond to the situation of the vertebræ. *Length* ten lines.

In the second month, most of the parts exist. The black points, which represented the eyes, enlarge in every dimension; the eyelids are sketched, and are extremely transparent; the nose begins to stand

out; the mouth increases, and becomes open; the brain is soft and pulpy, and the heart is largely developed. Prior to this period—very early indeed—substances or bodies are perceptible, which were first described, as existing in the fowl, by Wolff,[1] and in the mammalia by Oken,[2] and which have been called by the Germans, after their discoverers, Wolffische oder Okensche Körper ("bodies of Wolff or Oken"). According to J. Müller, they disappear in man very early, so that but slight remains of them are perceptible after the ninth or tenth week of pregnancy. They cover the region of the kidneys and renal capsules, which are formed afterwards, and are presumed to be organs of urinary secretion during the first periods of fœtal existence. The fingers and toes are now distinct. In the third month, the eyelids are more developed and firmly closed. A small hole is perceptible in the pavilion of the ear. The alæ nasi are distinguishable. The lips are very distinct, and approximate, so that the mouth is closed. The genital organs of both sexes undergo an extraordinary increase during this month. The penis is long; the scrotum empty, frequently containing a little water. The vulva is apparent, and the clitoris prominent. The brain, although still pulpy, is considerably developed, as well as the spinal marrow. The heart beats forcibly. The lungs are insignificant; the liver very large, but soft and pulpy, and appears to secrete scarcely any bile. The upper and lower limbs are developed. *Weight*, two and a half ounces; *length*, three and a half inches.

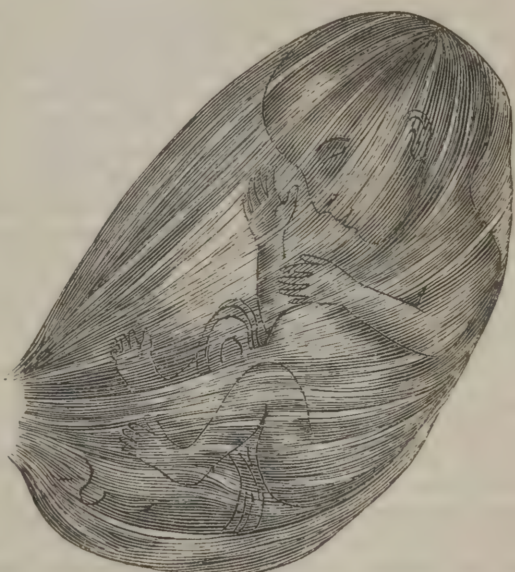
During the fourth month, all the parts

Fig. 486.

Corpora Wolffiana, with Kidney and Testes, from Embryo of Birds.

1. Kidney. 2, 2. Ureters. 3. Corpus Wolffianum. 4. Its excretory duct. 5, 5. Testicles. At the summit are seen the supra-renal capsules.

Fig. 487.



Fœtus at three months, in its membranes.

[1] Theoria Generationis, Hal., 1759.

[2] Oken und Kieser, Beiträge zur Vergleichend. Zoologie, Anatomie und Physiologie, H. i. p. 74, Bamburg und Würzburg, 1806; and Rathke, in Weber's Hildebrandt's Handbuch der Anatom., iv. 440.

acquire great developement and character, except perhaps the head and liver, which increase less in proportion than other parts. The brain and spinal marrow acquire greater consistence; the muscular system, which began to be observable in the preceding month is now distinct; and slight, almost imperceptible, movements begin to manifest themselves. The *length* of the fœtus is, at the end of one hundred and twenty days, five or six inches; the *weight*, four or five ounces. During the fifth month, the developement of every part goes on; but a distinction is manifest amongst them. The muscular system is well marked, and the movements of the fœtus unequivocal. The head is still very large, compared with the rest of the body, and is covered with small silvery hairs. The eyelids are glued together. *Length*, seven to nine inches; *weight*, six or eight ounces. If the fœtus be born at the end of five months, it may live for a few minutes.

In the sixth month, the derma begins to be distinguished from the epidermis. The skin is delicate, smooth, and of a purple colour; especially on the face, lips, ears, palms of the hands and soles of the feet. It seems plaited, owing to the absence of fat in the subcutaneous areolar tissue. The scrotum is small, and of a vivid red hue. The vulva is prominent, and its lips are separated by the projection of the clitoris. The nails appear, and towards the termination of the month are somewhat solid. Should the fœtus be born now, it is sufficiently developed to breathe and cry; but it generally dies in a short time. *Length*, at six months, ten or twelve inches. *Weight*, under two pounds.

During the seventh month all the parts are better proportioned. The head is directed towards the orifice of the uterus, and can be felt by the finger passed into the vagina, but it is still very movable. The eyelids begin to separate, and the membrane, which previously closed the pupil—*membrana pupillaris*—begins to disappear. The fat is more abundant, so that the form is more rotund. The skin is redder; its sebaceous follicles—which secrete a white, cheesy substance, *vernix caseosa*, that covers it—are formed; and the testicles are in progress to the scrotum. The vernix has been recently analyzed by Dr. John Davy,[1] and found to consist of

Epithelium (epidermis) plates, ...	13·25
Olein, ...	5·75
Margarin, ...	3·13
Water, ...	77·37

and in the very minute quantity of ashes that remained, there were traces of phosphate of lime and sulphur. It is, consequently, an excretory secretion from the skin. The *length*, at seven months, is fourteen inches; *weight*, under three pounds. In the eighth month, the fœtus increases proportionably more in breadth than in length. All its parts are firmer and more formed. The nails exist; and the child is now certainly *viable* or capable of supporting an independent existence. The testicles descend into the scrotum; the bones of the skull, ribs and limbs are more or less completely ossified. *Length*, sixteen inches; *weight*, four pounds and upwards.

[1] Medico-Chirurgical Transactions, xxvii. p. 189, Lond., 1844.

At the full period of nine months, the organs have acquired the developement necessary for the continued existence of the infant. *Length*, eighteen or twenty inches; *weight*, six or seven pounds. According to Dr. Granville, its *length* is twenty-two inches; *weight* from five to eight pounds. Dr. Dewees[1] says the result of his experience, in this country, makes the average weight about seven pounds. He has met with two ascertained cases of fifteen pounds, and many that he believed to be of equal weight. Dr. Moore, of New York, had several cases, where the weight was twelve pounds; and a case occurred in that city in 1821, of a fœtus, born dead, which weighed sixteen and a half pounds. Dr. Traill[2] once weighed a child at the moment of birth; it weighed 14 pounds; Mr. Park, of Liverpool, found one weigh 15 pounds; and a case has been recorded by Mr. J. D. Owens, in which a still-born child measured 24 inches in length, and weighed 17 pounds 12 ounces.[3] Dr. Storer,[4] of Boston, has published the following results of observations. Of 30 children, 14 females weighed 112 pounds, or averaged 8 pounds each; and 16 males 145¼ pounds, or 8½ pounds each. The largest child seen by Dr. Storer was a male, which weighed 13 pounds; the next in weight was 12½ pounds. One weighed 11, one 10½, and two ten pounds each. The average weight of 836 children, recorded by Dr. Metcalf[5] of Mendon, Massachusetts, was eight pounds, five ounces, and a fraction. The males—429 in number—weighed eight pounds ten ounces each; the female—407 in number—eight pounds.

Dr. Clarke[6] gives the absolute and relative weight of 60 of each sex, as observed at the Dublin Hospital:—60 males weighed 442 lbs.; average 7 lbs., 5 oz., 2 dr. 60 females weighed 404¼ lbs.; average 6 lbs., 11 oz., 2 dr. Average difference 9 oz.

In the Edinburgh Lying-in Hospital, 50 male and 50 female children, born during the latter months of 1842, and the earlier part of 1843, were weighed by Dr. Simpson's assistant, Dr. Johnstone.[7] 50 males weighed 383 lbs., 11 oz., 4 dr.; average 7 lbs., 9 oz., 1 dr. 50 females weighed 342 lbs., 12 oz., 4 dr.; average 6 lbs., 12 oz. Average differenee about 10 oz.

The lengths of these were:—50 males, total length, 1020½ inches, average 20 inches, 5 lines. 50 females, total length, 990½ inches; average 19 inches, 10 lines. Average difference 7 lines, or upwards of half an inch.

When there are twins in utero, the weight of each is usually less than in a uniparous case; but their united weight is greater. M. Dugès, of Paris, found in 444 twins the average weight to be four pounds, and the extreme weights three, and eight pounds. At times,

[1] Compendious System of Midwifery, 8th edit., Philad., 1836.
[2] Outlines of a Course of Medical Jurisprudence, 2d edit., p. 16, Edinb., 1840, or American edition with notes by the author of this work, p. 27, Philad., 1841.
[3] London Lancet, Dec. 22, 1838.
[4] New England Quarterly Journal of Medicine and Surgery, July, 1842.
[5] American Journal of the Medical Sciences, Oct., 1847, p. 314.
[6] Philosophical Transactions, 1786.
[7] Edinburgh Medical and Surgical Journal, Oct., 1844; see, also, Dr. Simpson's Report of the Edinburgh Royal Maternity Hospital, in Monthly Journal and Retrospect of the Medical Sciences, Nov., 1848, p. 332.

however, they are very large. Dr. P. G. Bertolet, of Oley, Pennsylvania,[1] describes a twin case in which one child weighed nine pounds and a half,—the other, eleven and a quarter pounds,—the united weights being twenty pounds and three-quarters.

The whole of these estimates—as before remarked—give no more than an approximation to the general truth. The facts will be found to vary greatly in individual cases; which accounts for the great discordance in the statements of different observers. This is strongly exemplified in the following table, containing the estimates of the length and weight of the fœtus at different periods of intra-uterine existence, as deduced by Dr. Beck[2] from various observers, and as given by M. Maygrier[3] on his own authority, and by Dr. Granville[4] as the averages of minute and accurate observations made by Autenrieth, Sömmering, Bichat, Pockels, Carus, &c., confirmed by his own observation of several early ova, and of many fœtuses examined in the course of seventeen years' obstetrical practice. It is proper to remark, that the Paris pound, *poids de marc*, of sixteen ounces, contains 9216 Paris grains; whilst the avoirdupois contains only 8532·5 Paris grains; and that the Paris inch is 1·065977 English inch.

	Length.			Weight.		
	Beck.	Maygrier.	Granville.	Beck.	Maygrier.	Granville.
At 30 days,	3 to 5 lines	10 to 12 lines			9 or 10 grains	
2 months,	2 inches	4 inches	1 inch	2 ounces	5 drachms	20 grains
3 do.	3½ do.	6 do.	3 inches	2 or 3 do.	2½ ounces	1½ ounce
4 do.	5 to 6 do.	8 do.		4 or 5 do.	7 or 8 do.	
5 do.	7 to 9 do.	10 do.		9 or 10 do.	16 do.	
6 do.	9 to 12 do.	12 do.	9 do.	1 to 2 pounds	2 pounds	1 pound
7 do.	12 to 14 do.	14 do.	12 do.	2 to 3 do.	3 do.	2 to 4 pounds
8 do.	16 do.	16 do.	17 do.	3 to 4 do.	4 do.	4 to 5 do.

The difficulty must necessarily be great in making any accurate estimate during the early periods of fœtal existence; and the changes in the after months are liable to considerable fluctuation. M. Chaussier affirms, that after the fifth month, the fœtus increases an inch every fifteen days, and M. Maygrier adopts his estimate. The former gentleman has published a table of the dimensions of the fœtus at the full period, deduced from an examination of more than fifteen thousand cases. From these we are aided in forming a judgment of the probable age of the fœtus in the latter months of utero-gestation;—a point of interest with the medico-legal inquirer. At the full period, the middle of the body corresponds exactly with the umbilicus, or a very little below it; at eight months, it is three-quarters of an inch, or an inch higher. At seven months, it approaches still nearer the sternum; and at six falls exactly at the lower extremity of that bone; hence, if we were to depend upon these admeasurements, should the middle of the body of the fœtus be found to fall at the lower extremity of the sternum, we might be justified in concluding, that the fœtus is under the seventh month, and consequently not *viable* or rearable.

[1] Medical Examiner, for Aug., 1848, p. 472.
[2] Medical Jurisprudence, 6th edit., i. 276, Philad., 1838.
[3] Nouvelles Démonstrations d'Accouchemens, Paris, 1822–26.
[4] Graphic Illustrations of Abortion, &c., p. xi., Lond., 1834.

The following are the results of observations made by Dr. A. S. Taylor, Professor of Medical Jurisprudence and Chemistry at Guy's Hospital, and Dr. Geoghegan, Professor of Medical Jurisprudence to the Royal College of Surgeons in Ireland.

Case.	Whole length.	Attachment of the Umbilical Cord.	
1	$18\frac{1}{2}$	A quarter of an inch below the centre.	
2	20	Half an inch	Do.
3	$17\frac{1}{2}$	Half an inch nearly	Do.
4	$16\frac{1}{2}$	Half an inch	Do.
5	19	Do.	Do.
6	17	A little below the centre.	
7	18	Exactly at the centre.	
8	17	Do. Do.	
9	$20\frac{3}{4}$	A little below the centre.	
10	$19\frac{1}{4}$	Do. Do.	
11	$18\frac{3}{4}$	Exactly at the centre.[1]	

A striking circumstance connected with the developement of the fœtus is the progressive diminution in the proportion of the part of the body above the umbilicus to that below it. At a very early period of fœtal life (see Figs. 484 and 485), the cord is attached near the base of the trunk; but the parts beneath become gradually developed, until its insertion ultimately falls about the middle of the body.

The following table of the length and weight (French), and central point of the fœtus at different ages is given by M. Lepelletier.[2] It still farther exhibits the discordance alluded to above.

Month.	Length.	Weight.	Central point.
1	5 to 6 lines	9 to 15 grains	at the junction of the head and trunk.
2	18 to 20 lines	6 to 8 drachms	at the upper part of the sternum.
3	2 to 3 inches	2 to 3 ounces	at the upper extremity of the xiphoid cartilage.
4	5 to 6 inches	10 to 16 ounces	at the middle of the xiphoid cartilage.
5	7 to 9 inches	1 to 2 pounds	at the lower extremity of the xiphoid cartilage.
6	9 to 12 inches	2 to 3 pounds	several lines below the xiphoid cartilage.
7	12 to 15 inches	3 to 4 pounds	equidistant between the cartilage and the umbilicus.
8	15 to 18 inches	4 to 6 pounds	an inch above the umbilicus.
9	16 to 20 inches	6 to 8 pounds	at the umbilicus.
	Extremes.	*Extremes.*	
	12 to 15 inches (Millot).	2 to 16 pounds (Voistel).	

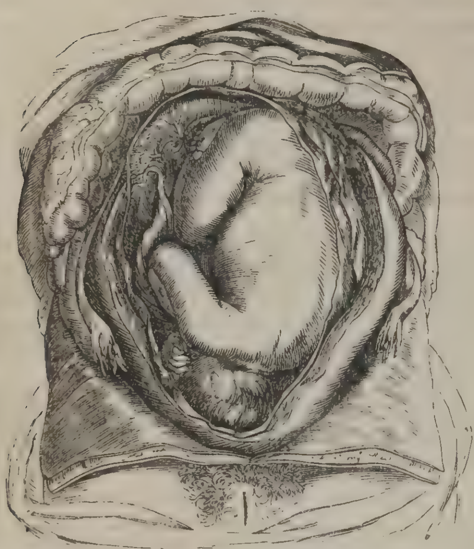
The position of the fœtus in utero, and the cause of such position at various periods of utero-gestation, have been topics of some interest. In the early weeks, it seems to be merely suspended by the cord; and it has been conceived, that owing to the weight of the head it is the lowest part. It is difficult, however, to admit this as the cause of the position in such an immense majority of cases, or to fancy, that the nice adaptation of the fœtal position to the parts through which the

[1] See, on all this subject, A. S. Taylor, Medical Jurisprudence, 3d Amer. edit. by Dr. E. Hartshorne, p. 286, Philad., 1853.

[2] Physiologie Médicale et Philosophique, iv. 451, Paris, 1833.

child has to pass is simply dependent upon such a mechanical cause. Gravity can afford us no explanation of the fact, referred to under Parturition, that the face in 12,120 cases of 12,533, has been found turned to the right sacro-iliac synchondrosis, and the occiput to the left acetabulum; and in the 63 of these cases in which the face was turned forwards, and in the 198 breech presentations, are we to presume, that this was owing to greater weight in these parts that were lowest. Dr. Simpson[1] affirms, that the usual position of the fœtus with the head lowest is not assumed until about the sixth month of intra-uterine life;—that both the assumption and maintenance of this position are vital acts, depending upon the vitality of the child, and ceasing at death; and that the cephalic attitude of the fœtus is the one best adapted to the normal shape of the fully developed uterus. The common position, at the full period, is exhibited in the last illustration. The body is bent forward, the chin resting on the chest: the occiput towards the brim of the pelvis; the arms approximated in front, and one or both lying upon the face; the thighs bent upon the abdomen; the knees separated; the legs crossed, and drawn up, and the feet bent upon the anterior surface of the legs; so that the oval, which it thus forms, has been estimated at about ten inches in the long diameter,—the head, at the full period, resting on the neck and even on the mouth of the womb, and the breech corresponding to the fundus of the organ.

Fig. 488.



Full period of Utero-Gestation.

It appears then, that from the first moment of a fecundating copulation, the minute matters furnished by the sexes, commingled, commence the work of developing the embryo. For a short time they find in the ovum the necessary nutriment, and subsequently obtain it from the uterus. The mode in which this action of developement is accomplished is as mysterious as the essence of generation itself. When the impregnated ovum is first seen it is as an amorphous, gelatiniform mass, in which no distinct organs are perceptible. In a short time, however, the brain and spinal marrow, and bloodvessels, make their appearance; but it has been a topic of controversy which of these is developed first.

[1] Monthly Journal of Medical Science, July, 1849.

Sir Everard Home,[1] from his own observations of the chick in ovo, as well as from the microscopic appearances presented by the ovum in the case of the female who died on the seventh or eighth day after impregnation, decides, that the organs first formed bear a resemblance to brain, and that the heart and arteries are produced in consequence of the formation of nervous centres. Malpighi, Brera, Pander, Tiedemann, Prévost and Dumas, Velpeau, Rolando, and Schröder van der Kolk,[2] also assign the priority to the nervous system. Meckel, however, admits no primitive organizing element, but believes,—properly, we think,—that the first rudiments of the fœtus contain the basis of every part. On the other hand, the researches of M. Serres on the mode of developement of the nervous system induce him to be in favour of the earlier appearance of the bloodvessels, and this view seems to be supported by the fact, that if an artery of the brain be wanting, or double, the nervous part to which it is usually distributed is equally wanting, or double. The acephalous fœtus has no carotid or vertebral arteries; and the bicephalous or tricephalous have them double or treble. With these views Dr. Granville[3] accords, and he lays it down as a law, that the nerves invariably appear after the arteries which they are intended to accompany.

A like discordance of ideas exists regarding the precedence in the formation of the heart and the bloodvessels. The blood is clearly formed before the heart. It appears at distinct points, and acquires a motion independently of it. The veins appear to be formed first; and then the heart and arteries. This is the view of perhaps the generality of histologists; but a distinguished Italian observer—Rolando—assigns the precedency to the arteries.

MM. Geoffroy Saint-Hilaire,[4] Meckel,[5] Serres,[6] Tiedemann,[7] and others are of opinion, that the developement of the embryo takes place from the sides towards the median line—from the circumference towards the centre; but M. Velpeau[8] thinks, that the median line is first formed. The spinal marrow is the first portion of the nervous system that appears; and this system, he believes, precedes every other. On all these deeply interesting but most intricate points of organogeny farther researches are demanded.

b. *Fœtal Dependencies.*

These are the parts of the ovum, that form its parietes, attach it to the uterus, connect it with the fœtus, and are inservient to the nutrition and developement of the new being.

They are generally conceived to consist,—*First*, of two membranes, according to common belief, which constitute the parietes of the ovule, and are concentric; the outermost, called *chorion*,—the innermost, filled with a fluid, in which the fœtus is placed, and called *amnion* or *amnios*.

[1] Lect. on Comp. Anat., iii. 292, and 429.

[2] Observationes Anatom. Pathol. et Pract. Argum., Amstel., 1826; cited in Edinb. Med. and Surg. Journal, for April 1, 1836.

[3] Op. cit.

[4] Philosophie Anatomique, Paris, 1818–22.

[5] Handbuch der Anatomie, Band. i.

[6] Recherches d'Anatomie Transcendante, &c., Paris, 1832.

[7] Anatomie du Cerveau, traduit par Jourdan, Paris, 1823.

[8] Embryologie ou Ovologie Humaine, Paris, 1833.

By Boer and Granville,[1] a third and outer membrane has been admitted,—the *cortical membrane* or *cortex ovi*. *Secondly*, of a spongy, vascular body, situate without the chorion, covering about one-quarter of the ovule, and connecting it with the uterus—the *placenta*. *Thirdly*, of a cord of vessels, called the *umbilical cord* or *navel string*—extending from the placenta to the fœtus, within which are vessels; and *lastly*, of two vesicles—the *umbilical*, and *allantoid*, and some have added a third—the *erythroid*, which are considered to be concerned in fœtal nutrition. As many of these dependencies have already fallen under consideration in certain of their relations, it will not be necessary to say much concerning them here.

1. *Chorion.*—The chorion—which has received various names—is the outermost of the membranes of the ovum. It has been already remarked (p. 529) that this envelope is considered to be received by the ovum as it passes along the Fallopian tube. Some, however, maintain that it is present in the ovum before it leaves the ovary; and it is so represented by Gerlach.[2] Generally, it is presumed to be formed from an albuminoid secretion of nucleated cells from the lining membrane of the Fallopian tube, and perhaps in addition from the zona pellucida, which disappears at this period. About the twelfth day after conception, according to M. Velpeau,[3] it is thick, opaque, resisting, and flocculent at both surfaces. These flocculi, in the part of the ovum that corresponds to the tunica decidua reflexa, aid its adhesion to that membrane; but in the part where the ovum corresponds to the uterus they become developed to constitute the placenta. At its inner surface, the chorion corresponds to the amnion. These two membranes are separated, during the earliest period of fœtal existence, by an albuminous fluid; but at the expiration of three months, the liquid disappears, and they are afterwards in contact. By many anatomists, the chorion is conceived to consist originally of two laminæ; and by Burdach[4] these have been distinguished by different names; the outer lamina being called *exochorion;* the inner, *endochorion*. M. Velpeau denies this; and asserts that he has never been able to separate them, even by the aid of previous maceration.

Fig. 489.

Entire Human Ovum of 8th week, sixteen lines in length (not reckoning the tufts); the surface of the Chorion partly smooth, and partly rendered shaggy by the growth of tufts.

As the placenta is formed on the uterine side of the chorion, the membrane is reflected over the fœtal surface of that organ, and is continued over the umbilical cord as far as the umbilicus of the fœtus, where it is confounded

[1] Graphic Illustrations of Abortion, Lond., 1834.

[2] Handbuch der Allgemeinen und Speciellen Gewebelehre des Menschlichen Körpers, 3te Lieferung, S. 341, Mainz, 1849.

[3] Embryologie, Paris, 1833.

[4] Physiologie als Erfahrungswissenschaft, ii. 57.

with the skin, of which it has consequently appeared to be a dependence. As pregnancy advances, the chorion becomes thinner, and less tenacious and dense, so that at the full period it is merely a thin, transparent, colourless membrane, much more delicate than the amnion. Haller, Blumenbach and Velpeau affirm it to be devoid of vessels; but, according to Wrisberg, it receives some from the umbilical trunks of the fœtus, and, according to others, from the decidua. M. Dutrochet conceives it to be an extension of the fœtal bladder. Its vascularity, according to Dr. Granville, is proved by its diseases, which are chiefly of an inflammatory character, ending in thickening of its texture; and he affirms, that there is a preparation in the collection of Sir Charles Clarke, which shows the vessels of the chorion as evidently as if they were injected.

2. *Amnion.*—The amnion—whose mode of formation has been described before—lines the chorion concentrically. It is filled with a serous fluid, and contains the fœtus. In the first days of fœtal existence, it is thin, transparent, easily lacerable, and somewhat resembling the retina. At first, it adheres to the chorion only by a point, which corresponds to the abdomen of the fœtus—the other portions of the membranes being separated by the fluid already mentioned, called *false liquor amnii.* Afterwards, the membranes coalesce, and adhere by very delicate areolar filaments; but the adhesion is feeble, except at the placenta and umbilical cord. In the course of gestation, this membrane becomes thicker and tougher; and, at the full period, is more tenacious than the chorion; elastic, semi-transparent, and of a whitish colour. Like the chorion, it covers the fœtal surface of the placenta, envelopes the umbilical cord, passes to the umbilicus of the fœtus, and there commingles with the skin.

It has been a question whether the amnion is supplied with bloodvessels. M. Velpeau denies it: Haller and others maintained the affirmative. Haller asserts that he saw a branch of the umbilical artery creeping upon it. The fact of the existence of a fluid within it, which is presumed to be secreted by it, would to a certain extent also favour the affirmative. But, admitting that it is supplied with bloodvessels, a difference has existed in regard to the source whence they proceed; and anatomical investigation has not succeeded in dispelling it. Dr. Monro affirms, that on injecting warm water into the umbilical arteries of the fœtus, the water oozed from the surface of the amnion. Wrisberg asserts, that he noticed the injection stop between the chorion and amnion; whilst M. Chaussier obtained the same results as Monro, by injecting the vessels of the mother.

The amnion contains a serous fluid, the quantity of which is in an inverse ratio to the size of the new being; so that its weight may be several drachms, when that of the fœtus is only a few grains. At first, the *liquor amnii,*—for so it is called,—is transparent; but, at the full period, it has a milky appearance, owing to flocculi of an albuminous substance held in suspension in it. It has a saline taste, a spermatic smell, and is viscid and glutinous to the touch. Vauquelin and Buniva[1]

[1] Annales de Chimie, tom. xxxiii.; and Mémoires de la Société Médicale d'Émulation, iii. 229.

found it contain, water, 98·8; albumen, chloride of sodium, soda, phosphate of lime, and lime, 1·2. That of the cow, according to these gentlemen, contains amniotic acid; but Prout, Dulong, Labillardière and Lassaigne were not able to discover it. Dr. Rees analyzed several specimens. He found its specific gravity to be about 1·007 or 1·008, and its mean composition in two cases at 7½ months, as follows: water, 986·8; albumen (traces of fatty matter), 2·8; salts soluble in water, 3·7; albumen from albuminate of soda, 1·6; salts soluble in alcohol, 3·4; lactic acid, urea, 1·7. Total, 1000. The salts consisted of chloride of sodium, and carbonate of soda, with traces of alkaline sulphate and phosphate. Vogt[1] analyzed it at two different periods of pregnancy, at 3½ months and 6 months, and found the constituents to vary as follows:—

	3½ Months.	6 Months.
Water,	978·45	990·29
Alcoholic extract, consisting of uncertain animal matter and lactate of soda,	3·69	0·34
Chloride of sodium,	5·95	2·40
Albumen (as residuum),	10·79	6·77
Sulphate and phosphate of lime, and loss,	0.14	0·30
	1000·	1000·
Specific gravity,	1·0182	1·0092

No inferences can, however, be drawn from these cases as to the proportion of solid matters at different periods of utero-gestation, inasmuch as the subject of the first case died of an inflammatory disease; the other of cachexia. Dr. Prout[2] found sugar of milk in the liquor amnii of the human female; Berzelius detected fluoric acid in it; Scheele, free oxygen;[3] and Lassaigne,[4] in one experiment, a gas resembling atmospheric air; in others, carbonic acid and nitrogen. Professor J. Müller,[5] however, was never able to detect oxygen in it. The chemical history of this substance is, consequently, sufficiently uncertain; nor is its origin placed upon surer grounds;—some physiologists ascribing it to the mother; others to the fœtus,—opinions fluctuating, according to the presumed source of the vessels that supply the amnion with arterial blood. It has even been supposed to be the transpiration of the fœtus, and its urine.

One reply to these views is, that we find it in greater relative proportion when the fœtus is small. Meckel thinks, that it chiefly proceeds from the mother, but that, about the termination of pregnancy, it is furnished in part by the fœtus. The functions, however, to which, as we shall see, it is probably inservient, would almost constrain us to regard it as a secretion from the maternal vessels; and what perhaps favours the idea is the asserted fact, that if a female has been taking rhubarb for some time prior to parturition, the liquor amnii has been found tinged by it.[6] It is interesting, also, to recollect, that, in the

[1] Müller's Archiv.; cited in Brit. and For. Med. Review, July, 1838, p. 248.

[2] Annals of Philosophy, v. 417.

[3] Dissert. de Liquoris Amnii Arteriæ Asperæ Fœtuum Humanorum Naturâ et Usu, &c., Copenh., 1799.

[4] Archiv. Général. de Méd., ii. 308.

[5] Handbuch der Physiologie, i. 305, Berlin, 1833.

[6] Cazeaux, Traité Théorique et Pratique de l'Art des Accouchements, p. 176, Paris, 1840.

experiments of Dr. Blundell,—which consisted in obliterating the vulvo-uterine canal in rabbits, and, when they had recovered from the effects of the injury, putting them to the male,—although impregnation did not take place, the womb, as in extra-uterine pregnancy, was developed, and the waters collected in it. The fluid, consequently, must, in these cases, have been secreted from the interior of the uterus. May not the liquor amnii be secreted in this manner throughout the whole of gestation, and pass through the membranes of the ovum by simple imbibition? and may not the fluid secretions of the fœtus, which are discharged into the liquor amnii, traverse the membranes, and enter the system of the mother in the same way?

The quantity of the liquor amnii varies in different individuals, and in the same individual at different pregnancies, from four fluidounces to as many pints. Occasionally, it is to such an amount as to throw obscurity even over the very fact of pregnancy. An instance of the kind, strongly elucidating the necessity of the most careful attention on the part of the practitioner, occurred in the practice of a respectable London practitioner,—a friend of the author. The abdomen of a lady had been for some time enlarging by what was supposed to be abdominal dropsy; fluctuation was evident, yet the case was equivocal. A distinguished accoucheur, and a surgeon of the highest eminence, were called in consultation, and after examination the latter declared, that "it was an Augean stable, which nothing but the trocar could clear out." As the lady, however, was even then complaining of intermittent pain, it was deemed prudent to make an examination *per vaginam*. The os uteri was found dilated and dilating; and in a few hours after this formidable decision, she was delivered of a healthy child, the gush of liquor amnii being enormous. After its discharge, she was reduced to the natural size, and the *dropsy*, of course, disappeared.

3. *Cortical membrane* or *cortex ovi.* This is, according to Boer and Granville,[1] the membrane that is usually regarded as a uterine production, and denominated *decidua reflexa.* In the view of Boer, it surrounds the ovule when it descends into the uterus, and envelopes the shaggy chorion. This membrane is destined to be absorbed during the first months of utero-gestation, so as to expose the next membrane to the contact of the decidua; with which a connexion takes place in the part where the placenta is to be formed. In that part, Boer and Granville consider, that the cortex ovi is never altogether obliterated, but only made thinner; and in process of time it is converted into a mere pellicle or envelope, which not only serves to divide the filiform vessels of the chorion into groups or cotyledons, in order to form the placenta, but also covers those cotyledons. This Dr. Granville calls *membrana propria.* The cortical membrane is not admitted by physiologists.

4. *Placenta.*—This is a soft, spongy, vascular body, formed at the surface of the chorion, adherent to the uterus, and connected with the fœtus by the umbilical cord. It is not in existence during the early period of the embryo state; but its rudimental formation commences, perhaps, with the arrival of the embryo in the uterus. In the opinion

[1] Graphic Illustrations of Abortion, part. iv., Lond., 1835.

of some, the flocculi, which are at first spread uniformly over the whole external surface of the chorion, gradually congregate from all parts of the surface into one, uniting with vessels proceeding from the uterus, and traversing the decidua, to form the placenta;—the decidua disappearing from the uterine surface of the placenta about the middle of pregnancy, so that the latter comes into immediate contact with the uterus. In the opinion of others, it is formed by the separation of the layers of the chorion, and by the developement of the different vessels that creep between them. M. Velpeau[1] maintains, that the placenta forms only at the part of the ovule which is not covered by the true decidua, and which is immediately in contact with the uterus; and that it results from the developement of the granulations which cover this part of the chorion;—these granulations or villi, according to him, being gangliform organs containing the rudiments of the placental vessels. Others, again, regard it as formed by the growth of the vessels of the uterus into the decidua serotina. An accurate histologist, Professor Goodsir,[2] has investigated this subject, and the following is his account of the incipient formation of the placenta from the elements supplied by the vascular villi of the chorion on the one hand, and the decidua on the other. The vessels of the decidua enlarge, and assume the appearance of sinuses, encroaching on the space formerly occupied by the cellular decidua, in the midst of which the villi of the chorion are embedded. The increase in the caliber of the decidual capillaries proceeds to such an extent, that the villi are finally completely bound up and covered by the membrane that constitutes the walls of the vessels,—this membrane filling the contour of all the villi, and even passing to a certain extent over the branches and stems of the tufts. Between this membrane or wall of the enlarged decidual vessels, and the internal membrane of the villi, there still remains a layer of the cells of the decidua. From this up to the full period, all that portion of decidua in connexion with the group of enlarged capillaries and vascular tufts of the chorion, and which, according to Mr. Goodsir, may be now called a placenta, is divided into two portions. The first portion of the decidua in connexion with the placenta, or forming a part of it, is situate between that organ and the wall of the uterus. "This," says Mr. Goodsir, "is the only portion of the placental decidua, with which anatomists have been hitherto acquainted, and I shall name it the parietal portion. It has a gelatinous appearance, and consists of rounded or oval cells. Two sets of vessels pass into it from the uterus. The first set includes vessels of large size, which pass through it for the purpose of supplying the placenta with maternal blood for the use of the fœtus. These may be named the maternal functional vessels of the placenta. The second set are capillary vessels, and pass into this portion of the decidua for the purpose of nourishing it. They are the nutritive vessels of the placenta."

The mode in which the placenta is attached to the uterus has been an interesting question with physiologists; and it has been revived, of

[1] Embryologie ou Ovologie Humaine, p. 63.
[2] Anatomical and Pathological Considerations, p. 60, Edinb., 1845.

late years, by Messrs. Lee,[1] Radford,[2] and others. A common opinion has been, that the large venous canals of the uterus are uninterruptedly continuous with those of the placenta. Wharton and Reuss,[3] and a number of others, conceive, that at an early period of pregnancy the part of the uterus in contact with the ovum becomes fungous or spongy, and that the *fungosities*, which constitute the uterine placenta, commingle and unite with those of the chorion so intimately, that laceration necessarily occurs when the placenta is extruded; and M. Dubois goes so far as to consider milk fever as a true traumatic disease, produced by such rupture. The opinion of Messrs. Lee, Radford, Velpeau, and others is, that the maternal vessels do not terminate in the placenta; but that apertures—portions scooped out, as it were,—exist in the parietes of those vessels, which are closed up, according to the two first gentlemen, by the true decidua;—according to M. Velpeau, by a membranule or anorganic pellicle, which he conceives to be thrown out on the fungous surface of the placenta,—or by some valvular arrangement, the nature of which has not been discovered; but these apertures have no connexion, in his opinion, with any vascular orifice either in the membrane or placenta. The mode, therefore, in which these authors consider the placenta to be attached to the uterus is, so far as it goes, somewhat unfavourable to the idea generally entertained, that the maternal vessels pour their fluid into the maternal side of the placenta, whence it is taken up by the radicles of the umbilical vein. Whatever blood is exhaled must necessarily pass through the decidua, according to Messrs. Lee and Radford; or through the pellicle, according to M. Velpeau. Subsequently Dr. Lee[4] somewhat modified his views, and expressed a belief, that the circulation in the human ovum, in the third month of gestation, is carried on in the following manner:—The maternal blood is conveyed by the arteries of the uterine decidua into the interstices of the placenta and villi of the chorion. The blood, which has circulated in the placenta, is returned into the veins of the uterus by the oblique openings in the decidua covering the placenta. The blood which has circulated between the villosities of the chorion, passes through the opening in the decidua reflexa into the cavity between the two deciduous membranes, whence it is taken up by the numerous apertures and canals that exist, according to him, in the uterine decidua; and so passes into the veins of the uterus. Biancini[5] maintains, that a number of flexuous vessels connect the uterus directly with the placenta, which are developed immediately after the period of conception. These utero-placental vessels, he says, are not prolongations of the uterine vessels, but a new production.

The late Dr. John Reid[6] carefully examined this point of anatomy. On cautiously separating the adhering surfaces of the uterus and pla-

[1] Philosoph. Trans. for 1822; and Remarks on the Pathology and Treatment of some of the most important Diseases of Women, Lond., 1833.

[2] On the Structure of the Human Placenta, Manchester, 1837.

[3] Novæ quædam Observationes circa Structuram Vasor. in Placent. Human. et peculiarem hujus cum Utero Nexum, Tubing., 1784.

[4] London Med. Gazette, Dec., 1838.

[5] Sul Commercio Sanguigno tra la Madre e il Feto, Pisa, 1833.

[6] Edinburgh Med. and Surg. Journal, Jan., 1841, p. 4.

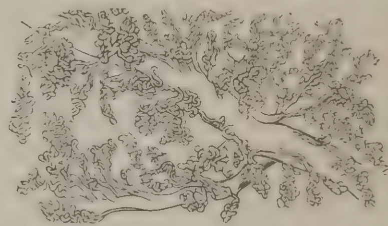
centa under water, he satisfied himself, but not without considerable difficulty, of the existence of the utero-placental vessels described by the Hunters. After a portion of the placenta had been detached in this manner, Dr. Reid's attention was attracted towards a number of rounded bands passing between the uterine surface of the placenta and the inner surface of the uterus, several of which could be drawn out in the form of tufts from the uterine sinuses. On slitting up some of the sinuses with the scissors, the tufts could be seen ramifying in their interior. These were ascertained to be prolongations of the fœtal placental vessels, and to protrude into certain of the uterine sinuses, and in those placed next the inner surface of the uterus only. These tufts were surrounded externally by a soft tube, similar to the soft wall of the utero-placental vessels, which passed between the margin of the open mouths of the uterine sinuses and the edges of the orifices in the decidua through which the tufts protruded into the sinuses. On examining the tufts, as they lay in the sinuses, it was evident, that

Fig. 490.

The Extremity of a Villus magnified 200 diameters.

The loop, 1, is filled with blood; the other loop, 2, is empty; 3 is the margin of the pellucid villus.

Fig. 491.



Portion of the ultimate ramifications of the Umbilical vessels, forming the Fœtal Villi of the Placenta.

Fig. 492.

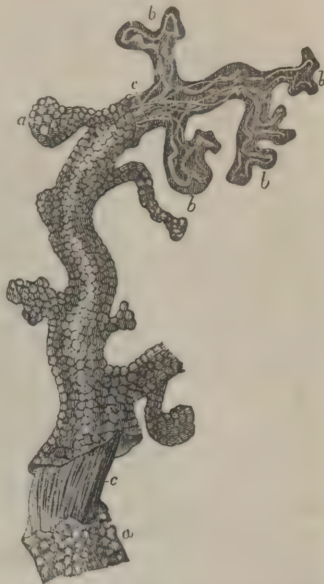
Diagram of the structure of the Placenta,

Showing *a*, the substance of the uterus. *b*. The cavity of a sinus. *c*. Curling arteries. *d, d*. The decidual lining of the uterus. *e, e*. The fœtal tufts dipping down into this.

though they were so far loose, and could be floated about, yet they were bound down firmly at various points by reflections of the inner coat of the venous system of the mother upon their outer surface. Dr. Reid farther satisfied himself, that the interior of the placenta is composed of numerous trunks and branches, each including an artery and an accompanying vein, every one of which, he believes, is closely en-

sheathed in prolongations of the inner coat of the vascular system of the mother, or at least in a membrane continuous with it. According to this idea of the structure of the placenta, the inner coat of the vascular system of the mother is prolonged over each individual tuft, so that when the blood of the mother flows into the placenta through the curling arteries of the uterus, it passes into a large sac formed by the inner coat of the vascular system of the mother, which is intersected in many thousands of different directions by the placental tufts projecting into it like fringes, and pushing its thin wall before them, in the form of sheaths, that closely envelope the trunk and each individual branch composing these tufts.

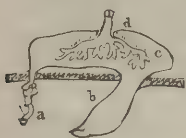
Fig. 493.



Portion of one of the Fœtal Villi, about to form part of the Placenta, highly magnified.

a, a. Its cellular covering. *b, b, b.* Its looped vessels. *c, c.* Its basis of connective tissue.

Fig. 494.



Connexion between the Maternal and Fœtal Vessels.

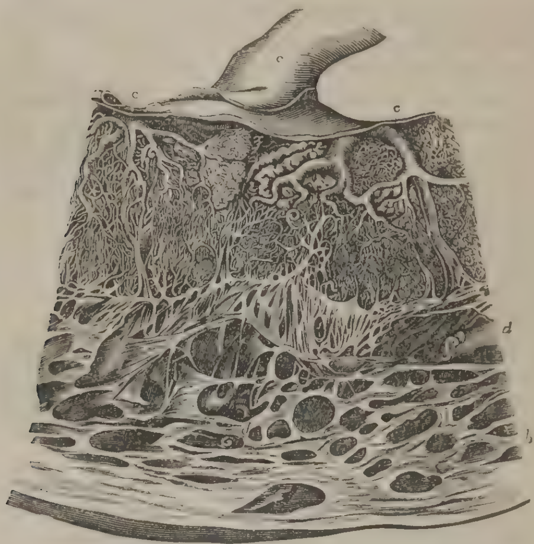
a. Curling artery. *b.* Uterine vein. *c.* Placenta. *d.* Placental tufts with inner coat of vascular system of the mother enveloping them.

From this sac, the maternal blood is returned by the utero-placental veins without having been extravasated, or without having left the maternal system of vessels. Into this sac in the placenta containing the blood of the mother, the tufts of the placenta hang like the branchial vessels of certain aquatic animals, to which they have a marked analogy. This sac is protected and strengthened on the fœtal surface of the placenta by the chorion, on the uterine surface by the decidua vera, and on the edges or margin by the decidua reflexa.

In this view, the fœtal and maternal portions are everywhere intimately intermixed with tufts of minute placental vessels, their blunt extremities being found lying immediately under the chorion covering its fœtal surface, as well as towards its uterine surface. The discovery of the prolongations of the fœtal placental vessels into some of the uterine sinuses, Dr. Reid thinks, is principally valuable, as it presents us with a kind of miniature representation of the whole structure of the placenta; and the reason why the placental tufts are not perceptible on the uterine surface of the placenta expelled in an accouchement is, that they are so strongly bound down by the reflection of the inner coat of the uterine sinuses that they are torn across. Professors Alison, Allen Thomson, and J. Y. Simpson inspected the preparations of Dr. Reid, and expressed themselves satisfied, that the placental tufts were

prolonged into the uterine sinuses, and that the inner coat of the veins was prolonged upon them. Dr. Sharpey, too, confirms the views of Dr.

Fig. 495.



Section of a portion of a fully-formed Placenta, with the part of the Uterus to which it is attached.

a. Umbilical cord. *b*, *b*. Section of uterus, showing the venous sinuses. *c*, *c*, *c*. Branches of the umbilical vessels. *d*, *d*. Curling arteries of the uterus.

Reid from his own observation of impregnated uteri; and Dr. Churchill[1] states, that in a visit to Edinburgh, Dr. Reid showed him one of the portions of uterus and placenta on which his investigations were made, and there was no difficulty in demonstrating the tufts dipping into the uterine sinuses. "No doubt," he adds, "farther observations are necessary for the perfect elucidation of the subject; but I certainly think, that as far as our knowledge extends, it is in favour of the opinion adopted by Dr. Reid and the later physiologists." A somewhat similar view to that of Dr. Reid is entertained by Prof. E. H. Weber.[2]

The fœtal placental tufts, when injected, form beautiful preparations.

Since Dr. Reid's observations were made, Professor Goodsir[3] has discovered on the fœtal tufts villi like those of the intestinal canal, and internal cells on the tufts, which he considers to be precisely analogous to those of the intestinal villi, described in the first volume of this work. "Within the internal membrane," he remarks, "and on the external surface of the umbilical capillaries, are cells, which I have named the internal cells of the tuft. When the vessels are engorged, these cells

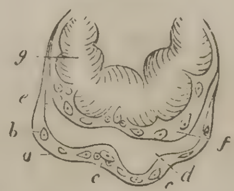
[1] The Theory and Practice of Midwifery, Amer. edit., by Dr. Condie, p. 119, Philad., 1851.

[2] Hildebrandt, Handbuch der Anatomie des Menschen, iv. 496, Braunschweig, 1832.

[3] Anatomical and Pathological Observations, Edinburgh, 1845.

are seen with difficulty. When the vessels are moderately distended, and the internal membrane separated from the external cells by moderate pressure, the cells now under consideration come into view. They are best seen in the spaces left between the internal membrane and the retiring angles formed by the coils or loops of the vessels, and in the vacant spaces formed by these loops. These cells are egg-shaped, highly transparent, and are defined by the instrument with difficulty; but their nuclei are easily perceived. They appear to be filled with a highly transparent refractive matter. This system of cells fills the whole space that intervenes between the internal membrane of the villus and the vessels, and gives to this part of the organ a mottled appearance." The function of the external cells of the placental villi is, in Mr. Goodsir's view, to separate from the blood of the mother the matter destined for the blood of the fœtus. "They are, therefore, secreting cells, and are the remains of the secreting mucous membrane of the uterus." The cells within the placental villi—the "internal cells" referred to above—belong to the system of the fœtus. They are the cells of the villi of the chorion, and their function is to absorb "the matter secreted by the agency of the external cells of the villi." The placenta, consequently, in Mr. Goodsir's view, performs not only the function of a lung, but that of an intestinal tube.

Fig. 496.



Extremity of a Placental Villus.

a. External membrane of the villus, continuous with the lining membrane of the vascular system of the mother. *b.* External cells of the villus, belonging to the placental decidua. *c, c.* Germinal centres of external cells. *d.* The space between the maternal and fœtal portions of the villus. *e.* The internal membrane of the villus, continuous with the external membrane of the chorion. *f.* The internal cells of the villus, belonging to the chorion. *g.* The loop of umbilical vessels.

In whatsoever manner primarily formed, the placenta is distinguishable in the second month, at the termination of which it covers two-thirds, or at least, one-half of the ovum: after this, it increases in size, but far less rapidly than the ovum. Prior to the full term, however, it is said to be less heavy, more dense, and less vascular, owing—it has been conceived—to several of the vessels that formed it having become obliterated and converted into hard fibrous filaments; a change, which has been regarded as a sign of maturity in the fœtus, and a prelude to its birth. At the full period, its extent has been estimated at about one-fourth of that of the ovum; its diameter from six to nine inches; circumference twenty-four inches; thickness from an inch to an inch and a half at the centre, but less than this at the circumference; and its weight, with the umbilical cord and membranes, at from twelve to twenty ounces. All this is subject, however, to much variation. Of 325 observed cases in the Edinburgh Royal Maternity Hospital,[1] the average weight was lb. 1, oz. 4, dr. 14 [?] Its shape is circular, and the cord is usually inserted into its centre. It may be attached to any part of the uterus, but is usually found towards the fundus. Of its two surfaces, that which corresponds to the uterus is divided into irregularly rounded lobes or

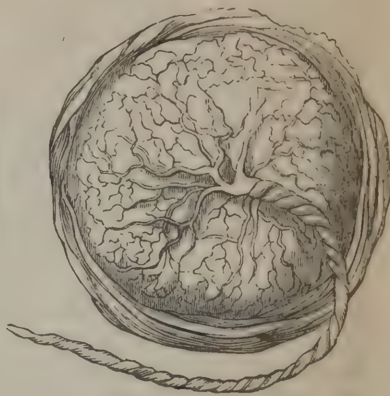
[1] Monthly Journal and Retrospect of the Medical Sciences, Nov., 1848, p. 332.

cotyledons, and is covered by a soft and delicate areolo-vascular membrane, which, by many, is considered to be decidua vera. Wrisberg,[1]

Fig. 497.

Uterine Surface of the Placenta.

Fig. 498.



Fœtal Surface of the Placenta.

Lobstein,[2] and Desormeaux,[3] however, who consider, that the decidua disappears from behind the placenta about the fourth or fifth month, regard it as a new membrane; and Bojanus, believing it to be produced at a later period than the decidua vera, gives it the name of *decidua serotina*.[4] (See Fig. 443, page 489 of this volume.) M. Breschet, again, affirms, that two laminæ—*decidua vera* and *decidua reflexa*—are found intervening between the uterus and placenta,[5] whilst M. Velpeau maintains that the true decidua never exists there! The *fœtal* or *umbilical surface* is smooth; polished; covered by chorion and amnion, and exhibits the distribution of the umbilical vessels, and the mode in which the cord is attached to the organ.

The following are the chief anatomical constituents of the placenta, as usually described by anatomists. *First.* Bloodvessels from two sources,—the mother and fœtus. The former proceed from the uterus, and consist of arteries and veins, the arteries of small size but of considerable number. The vessels, which proceed from the fœtus, are those contained in the umbilical cord—the umbilical vein, and umbilical arteries. These vessels, after having penetrated the fœtal surface of the placenta, divide in the substance of the organ, so that each lobe and perhaps each ultimate tuft has an arterial and a venous branch, which ramify in it, but do not anastomose with the vessels of other lobes. *Secondly.* White filaments, which are numerous in proportion to the advancement of pregnancy, and seem to be obliterated vessels. *Thirdly.* Intermediate areolar tissue, serving to unite the vessels together, and which has been regarded, by some anatomists, as an extension of the decidua accompanying those vessels. *Lastly.* A quantity of blood con-

[1] Observ. Anat. Obstetric. de Structurâ Ovi et Secundinar. Human., &c., Gotting., 1783.
[2] Essai sur la Nutrition du Fétus, Strasbourg, 1802.
[3] Art. Œuf Humain, in Dict. de Médecine.
[4] Isis, von Oken, für 1821.
[5] Mémoir. de l'Academ. Royal. de Médec., tom. ii., Paris, 1833.

tained in the ultimate maternal and fœtal vessels. In addition to these constituents, lymphatic vessels have been presumed to exist in it. Fohmann[1] affirms, that in addition to the bloodvessels, the umbilical cord consists of a plexus of absorbents, which may be readily injected with mercury. This has been done, also, by Dr. Montgomery, of Dublin. The lymphatics of the cord communicate with a net-work of lymphatics, seated between the placenta and amnion, the termination of which Fohmann could not detect, but, he thinks, they pass to the uterine surface of the placenta. These proceed to the umbilicus of the child, and chiefly unite with the subcutaneous lymphatics of the abdominal parietes; follow the superficial veins; pass under the crural arches; ramify on the iliac glands; and terminate in the thoracic duct. Lobstein and Meckel, however, were never able to detect lymphatics in the cord.

Chaussier and Ribes,[2] and Mr. Cæsar Hawkins[3] describe nerves in the placenta which they refer to the great sympathetic of the fœtus.

The uterine and fœtal portions of the placenta are generally described as quite distinct from each other during the first two months of fœtal life; but afterwards as constituting one mass. The uterine vessels remain distinct from the fœtal—the uterine arteries and veins communicating freely with each other, as well as the fœtal arteries and veins; but no direct communication exists between the maternal and fœtal vessels. Until of late, almost every obstetrical anatomist adopted the division of the placenta into two parts, constituting—as it were—two distinct placentæ,—the one maternal, the other fœtal. Messrs. Lee, Radford, and others, however, contested this point, and affirmed, with M. Velpeau, that the human placenta is entirely fœtal. If, indeed, the idea of M. Velpeau were true, that a membrane, or as he calls it,—"membranule," exists between the placenta and the uterus, it would destroy the idea of any direct adhesion between the placenta and uterus, and make the placenta wholly fœtal. Yet the point—as we have seen—is still contested,—by those especially, who consider that both the maternal and fœtal vessels ramify in the placenta, a view now embraced by the best histologists.

It is generally supposed, that the placenta is most frequently attached to the right side of the uterus, but Nägele[4] found the opposite to be the fact in his examinations. In six hundred cases, which he carefully auscultated, it was met with in two hundred and thirty-eight cases on the left side, and in one hundred and forty-one on the right.

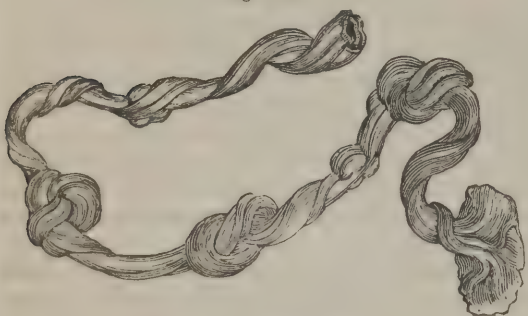
5. *Umbilical cord.*—From the fœtal surface of the placenta a cord of vessels passes, which enters the umbilicus of the fœtus, and has hence received the names *Funis*, *F. umbilicus*, *umbilical cord*, and *navel string*. It forms the medium of communication between the fœtus and placenta. During the first month—Pockels[5] says the first three weeks—of fœtal

[1] Sur les Vaisseaux Absorbans du Placenta, &c., Liège, 1832; and Amer. Journ., May, 1835, p. 174.
[2] Journal Universel des Sciences Médicales, i. 233.
[3] Sir E. Home, Lect. on Comp. Anat., v. 185, Lond., 1828.
[4] Die Geburtshülfliche Auscultation, Mainz, 1838; cited in Brit. and For. Med. Rev., Oct., 1839, p. 371.
[5] Neue Beiträge zur Entwickelungsgeschichte des Menschlichen Embryo, in Isis, von Oken, 1825.

existence, the cord is not perceptible; the embryo appearing to be in contact, by the anterior part of its body, with the membranes of the ovum. Such, at least, is the description of most anatomists; but M. Velpeau[1] says it is erroneous. The youngest embryo that he dissected had a cord. At from a fortnight to three weeks old, its length is three or four lines; and he thinks his examinations lead him to infer, that at every period of fœtal developement, its length is nearly equal to that of the body, if it does not exceed it a little.

In an embryo a month old, M. Béclard[2] observed vessels creeping, for a certain space, between the membranes of the ovum, from the abdomen of the fœtus to a part of the chorion, where the rudiments of the future placenta were visible. During the fifth week, the cord is straight, short, and very large, owing to its containing a portion of intestinal canal. It presents, also, three or four dilatations, separated by as many contracted portions or necks; but these gradually disappear; the cord lengthens, and becomes smaller, and occasionally it is twisted, knotted, and tuberculated in a strange manner. (Fig. 499.) After the fifth week it contains — besides the duct of the umbilical vesicle—the omphalo-mesenteric vessels, and a portion of the urachus or of the allantoid vesicle and intestines. At about two months, the digestive canal enters the abdomen: the urachus, the vitelline canal, and the vessels become obliterated, so that, at three months, as at the full period, the cord is composed of three vessels,—the umbilical vein, and two arteries of the same name,—of a peculiar jelly-like substance, and is surrounded, as we have seen, by the amnion and chorion. These are united by an areolar tissue, containing the *jelly of the cord*, or *jelly of Wharton*, a thick albuminous secretion, which bears some resemblance to jelly, and the quantity of which is very variable. In the fœtus, the areolar tissue is continuous with the sub-peritoneal areolar tissue; and in the placenta, it is considered to accompany the ramifications of the vessels. The length of the cord varies, at the full period, from eight inches to fifty-four. The most common length is eighteen inches.

Fig. 499.



Knotted Umbilical Cord.

It has been already remarked, that Chaussier, Ribes, and Hawkins have traced branches of the great sympathetic of the fœtus as far as the placenta; and the same has been done by Durr,[3] Rieck,[4] and others.

6. *Umbilical vesicle.*—This vesicle, called also *vesicula alba* and *intes-*

[1] Embryologie ou Ovologie Humaine, Paris, 1833.
[2] Embryologie ou Essai Anatomique sur le Fétus Humain, Paris, 1821.
[3] Dissert. Sistens Funicul. Umbilic. Nervis Carere, Tubing., 1815.
[4] Utrum Funiculus Umbilicalis Nervis polleat aut careat., Tubing., 1816.

tinal vesicle, appears to have been first carefully observed by Albinus.[1] Dr. Granville,[2] however, ascribes its discovery to Bojanus,[3] whilst others have assigned it to Diemerbroeck.[4] It was unknown to the ancients; and, amongst the moderns, is not universally admitted to be a physiological condition. Osiander and Döllinger class it amongst imaginary organs; and M. Velpeau remarks, that out of about two hundred vesicles, which he had examined, in fœtuses under three months of developement, he had met with only thirty in which the umbilical vesicle was in a state that could be called natural. Under such circumstances, it is not easy to understand how he distinguished the natural from the morbid condition. If the existence of the vesicle be a part of the natural process, the majority of vesicles ought to be healthy or natural; yet he pronounces the thirty in the two hundred to be alone properly formed; and, of consequence, one hundred and seventy to be morbid or unnatural. This vesicle is described as a small pyriform, round or spheroidal sac; which, about the fifteenth or twentieth day after fecundation, is of the size of a common pea. It probably acquires its greatest dimensions in the course of the third or fourth week. After a month, M. Velpeau always found it smaller. About the fifth, sixth, or seventh week, it is about the size of a coriander seed. After this, it becomes shrivelled, and disappears insensibly. It seems to be situate between the chorion and amnion, and is commonly adherent either to the outer surface of the amnion, or the inner surface of the chorion; but, at times, is situate loosely between them. It is seen in Figs. 443, 476, 477, and 480.

The characters of the *vitelline pedicle*, as M. Velpeau terms it, which attaches the vesicle to the embryo, vary according to the stage of gestation. At the end of the first month, it is not less than two, nor more than six lines long, and about a quarter of a line broad. Where it joins the vesicle, it experiences an infundibuliform expansion. Its continuity with the intestinal canal appears to be undoubted.[5] Up to twenty or thirty days of embryonic life, the pedicle is hollow, and, in two subjects, M. Velpeau was able to press the contained fluid from the vesicle into the abdomen, without lacerating any part. Generally, the canal does not exist longer than the expiration of the fifth week, and the obliteration appears to proceed from the umbilicus towards the vesicle. The parietes of the *vitelline pouch*—as M. Velpeau calls it, from its analogy to the vitelline or yolk-bag of the chick—are strong and resisting; somewhat thick, and difficult to tear.

As the umbilical vesicle of brutes has been admitted to be continuous with the intestinal canal, anatomists have assigned it and its pedicle three coats. Such is the view of M. Dutrochet. M. Velpeau has not been able to detect these in the human fœtus. He admits, however, a serous surface, and a mucous surface. The vesicle—as elsewhere remarked[6]—is supplied with arteries and veins, generally termed *omphalo-mesenteric* or *omphalo-meseraic*, but, by M. Velpeau, *vitello-*

[1] Annotat. Academic., lib. i. p. 74.
[2] Graphic Illustrations of Abortion, p. xii., Lond., 1834.
[3] Meckel's Archiv., iv. S. 34.
[4] Opera, p. 304, Ultraject., 1672.
[5] Purkinje, art. Ei, in. op. cit., x. 157.
[6] Page 536.

mesenteric, or, simply, *vitelline*. The common belief is, that they communicate with the superior mesenteric artery and vein; but M. Velpeau says he has remarked, that they inosculate with one of the branches of the second or third order of those great vessels (*canaux*),—with those, in particular, that are distributed to the cæcum. The fluid, contained in the vesicle, the *vitelline* fluid, was examined in a favourable case for the purpose by M. Velpeau, who found it of a pale yellow colour; opaque; of the consistence of a thickish emulsion; different in every respect from serosity, to which Albinus, Boerhaave,[1] Wrisberg[2] and Lobstein[3] compared it, and from every other fluid in the organism; and he regards it as a nutritive substance—a sort of oil—in a great measure resembling that which constitutes the vitelline fluid of the chick *in ovo*.

7. *Allantoid vesicle* or *allantois*.—This vesicle—called also *membrana farciminalis* and *membrana intestinalis*—has been alternately admitted and denied to be a part of the appendages of the human fœtus, from the earliest periods until the present day. It has been seen by Emmert, Meckel, Pockels, Velpeau, Von Baer, Burdach, and others; is situate between the chorion and amnion, and communicates, in animals, as before shown—with the urinary bladder by a duct called *urachus*. It has been observed in the dog, sheep, cow, in saurian and ophidian reptiles, birds, &c. M. Velpeau[4] was never able to detect any communication with the bladder in the human subject, and he is compelled to have recourse to analogy to infer, that any such communication in reality exists. From all his facts—which are not numerous or striking—he "thinks himself authorized to say," that from the fifth week after conception until the end of pregnancy, the chorion and amnion are separated by a transparent, colourless, or slightly greenish-yellow layer. This layer, instead of being a simple serosity, is lamellated after the manner of the vitreous humour of the eye. It diminishes in thickness in proportion to the developement of the other membranes. The quantity of fluid, which its meshes enclose, is, on the contrary, in an inverse ratio with the progress of gestation. It becomes gradually thinner and is ultimately formed into a homogeneous and pulpy layer, by being transformed into a simple gelatinous or mucous covering (*enduit*), which wholly disappears in many cases before the period of accouchement. Between the *reticulated body*, as M. Velpeau terms it, and the allantoid of oviparous animals, he thinks, there is the greatest analogy. Yet the fluid of the allantoid is very different from the urine, which is supposed, by some, to exist in the allantoid of animals. This fluid, we shall find, has been considered inservient to the nutrition of the new being, but, after all, it must be admitted, that our ideas regarding the vesicle, in man, are far from being determinate, for admitting—as elsewhere remarked—that it conveys the bloodvessels between the embryo and the chorion; the precise uses of its vesicular character and contents remain to be explained.

8. *Erythroid vesicle*.—This vesicle was first described by Dr. Pockels, of Brunswick, as existing in the human subject. It had been before

[1] Haller, Elementa Physiol., viii 208.
[2] Descript. Anat. Embryonis, Gotting., 1764.
[3] Op. cit., p. 42.
[4] Embryologie ou Ovologie Humaine, Paris, 1833.

observed in the mammalia. According to Pockels,[1] it is pyriform; and much longer than the umbilical vesicle, although of the same breadth. M. Velpeau, however, asserts, that he has never been able to meet with it; and he is disposed to think, that none of the embryos, depicted by Pockels, and by Seiler,[2] were in the natural state. Such, too, is the opinion of Weber,[3] and by the later embryologists the vesicle is not noticed.

According to most obstetrical physiologists, when pregnancy is multiple, the ova in the uterus are generally distinct, but contiguous to each other. By others, it has been affirmed, that two or more children may be contained in the same ovum, but this appears to require confirmation. The placenta of each child, in such multiple cases, may be distinct; or the different placentæ, having vascular communications with each other, may be united into one. At other times, in twin cases, but one placenta exists. This gives origin to two cords, and at others to one only, which afterwards bifurcates, and proceeds to both fœtuses. M. Maygrier,[4] however, and others[5] affirm unconditionally, that there is always a placenta for each fœtus; but that it is not uncommon, in double pregnancies, to find the two placentæ united at their margins; the circulation of each fœtus being distinct, although the vessels may anastomose. This was the fact in a case of quadruple pregnancy, communicated by M. Capuron to the *Académie Royale de Médecine*, Jan. 10th, 1837.

c. *Fœtal Peculiarities.*

The head of the fœtus is large in proportion to the rest of the body, and the bones of the skull are united by membrane; the sagittal suture extends down to the nose, so as to divide the frontal bone into two portions; and where this suture unites with the coronal, a quadrangular space is left, filled up by membrane, called *anterior fontanelle* or *bregma.* Where the posterior extremity of the sagittal suture joins the lambdoidal, a triangular space of a similar kind is left, called *posterior fontanelle* or *posterior bregma.* It is important for the obstetrical practitioner to bear in mind the shape of these spaces, as they indicate to him whether the anterior or posterior part of the head is the presenting part. The pupil of the eye, in a very young fœtus, is entirely closed by a membrane, called *membrana pupillaris,* which arises from the inner margin of the iris, and continues there till the seventh month, when it gradually vanishes by absorption. It is a vascular substance, and, like the iris, to which it is attached, separates the two chambers of the eye from each other. Wachendorff[6] first described it in 1738; and both he and Wrisberg detected vessels in it. Its vascularity was denied by Bichat, but it has been demonstrated by J. Cloquet.[7] The

[1] Isis, von Oken, p. 1342, 1825.

[2] Das Ei und Die Gabärmutter des Menschen. u. s. w., p. 24, Dresd., 1832.

[3] Hildebrandt, Handbuch der Anatomie, iv. 518, Braunsch., 1832.

[4] Nouvelles Demonstrations d'Accouchemens, Paris, 1822–26.

[5] Churchill, on the Theory and Practice of Midwifery, 3d Amer. edit., by Dr. Huston, p. 409, Philad., 1848.

[6] Commerc. Litterar. Noric., 1740; and Valentin, art. Fœtus, Encycl. Wörterb. u. s. w. xii. 376.

[7] Mémoire sur la Membrane Pupillaire, Paris, 1817.

membrane is manifestly connected with the process of formation of the delicate organ to which it is attached; and according to Blumenbach,[1] it keeps the iris expanded, during the rapid increase of the eyeball.

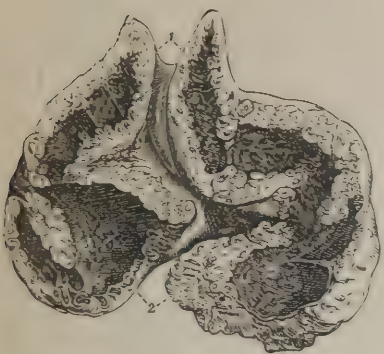
In the upper part of the thorax of the fœtus, a large gland, or rather glandiform ganglion exists, called *thymus*, and by Joseph Frank, *corpus incomprehensibile.* It is situate in the superior mediastinum, and lies over the top of the pericardium and arch of the aorta. It has two long cornua above, and two broad lobes below. Its appearance is glandular, and colour variable. In the progress of age it diminishes, so that in the adult it is wasted, and in old age can scarcely be discovered amongst the areolar tissue. Krause,[2] however, states, that he has found it in almost all individuals between twenty and thirty years of age, and often larger than in young children. The common idea is, that its greatest bulk is attained during the latter period of embryonic life; and that it must, consequently, exercise its chief functional activity during fœtal existence, and have some reference to the peculiarities of fœtal life. The observations of Krause do not sanction this idea; and the same may be said of those of Haugsted, who found not merely the absolute, but the relative size of the gland undergo a great increase after birth. Thus, whilst the weight of a dog's thymus at birth may range up to ten grains, it may subsequently increase with such rapidity, that after five months it may weigh nearly four hundred,—a proportional increase of forty times; whilst the weight of the entire animal has increased only twelve or sixteen times. Mr. Simon,[3] from his researches, agrees fully with Haugsted, and infers, that "the thymus can with no more propriety be referred to the needs and uses of fœtal life than the mammæ of the female can be considered subservient to the period of utero-gestation." The absolute increase of the gland appears to cease usually at about the age of two years.

The gland is surrounded by a thin, areolar capsule, which sends prolongations into its interior, and divides it into numerous hollow lobules of unequal size, whose cavities communicate with a central reservoir, from which there is no outlet. Each lobule, according to Kölliker,[4] may be regarded as a thick walled vesicle with protrusions, whose inner surface is even and continuous, whilst the outer is subdivided into gland granules or acini by more or less deep fissures. The vesicles are filled with a milky fluid, the actual and ultimate nature of which is said to be expressed by the formula for protein. It is, therefore, highly nutrient. Sir Astley Cooper[5] states, that the lobules may be drawn out and separated from each other in the manner of a string of beads, when their enveloping capsule has been removed. The ordinary weight of the thymus has been estimated at half an ounce; but this is probably above the average. Dr. Roberts,[6] of New York, found the average weight, in the full-grown fœtus, to

[1] Institut. Physiolog., § 262.
[2] Müller's Archiv., Heft 1, 1837.
[3] A Physiological Essay on the Thymus Gland, Lond., 1845.
[4] Amer. edit. of Sydenham Society's edition of his Manual of Histology, by Dr. Da Costa, p. 590, Philad., 1854.
[5] The Anatomy of the Thymus Gland, Amer. edit., p. 24. Philad., 1825.
[6] Amer. Journ. of the Med. Sciences, Aug., 1837, Nov., 1838, and Oct., 1841; New York Journ. of Med. and Surg., Jan., 1840; and New York Med. Gaz., July 21, 1841. Also, Dr. C. Lee, in Amer. Journ. of the Med. Sciences, Jan., 1842, p. 138.

be 229 grains. The thymic arteries proceed from the inferior thyroid, internal mammary, bronchial, mediastinal, &c. The nerves proceed

Fig. 500.



Section of Thymus Gland at the Eighth Month.

1. Cervical portions of gland; independence of two lateral glands is well marked. 2. Secretory cells seen upon cut surface of section; these are observed in all parts of section. 3, 3. Pores or openings of secretory cells and pouches; they are seen covering whole internal surface of great central cavity or reservoir. Continuity of reservoir in lower or thoracic portion of gland with cervical portion, is seen in the figure.

Fig. 501.

Portion of Thymus of Calf, unfolded.

a, Main canal; *b*, glandular lobules; *c*, isolated gland-granules seated on the main canal.

from the pneumogastric, diaphragmatic, and inferior cervical ganglia. It has no excretory duct; and is one of the most obscure in its physiology of any organ of the body, although, like the lymphatic glands, it is probably connected with lymphosis and the function of nutrition. By Mr. Hewson,[1] it was regarded as an appendage to the lymphatic glands for the more perfectly and expeditiously forming the "central particles of the blood" in the fœtus, and in the early part of life.

The fluid of the thymus has the appearance of chyle or cream, and contains a large number of corpuscles, which are smaller than the blood corpuscles, globular and oval in form; irregular in outline; variable in size; and provided with a small central nucleus.[2] These have been long regarded as identical with the chyle and lymph corpuscles. On treating the sliced thymus with ether, M. Renaud[3] found, that a considerable quantity of oleaginous matter was obtained from it; hence there is great resemblance between its composition, and that of chyle and milk.

According to Mr. Simon,[4] in hibernating animals, in which the

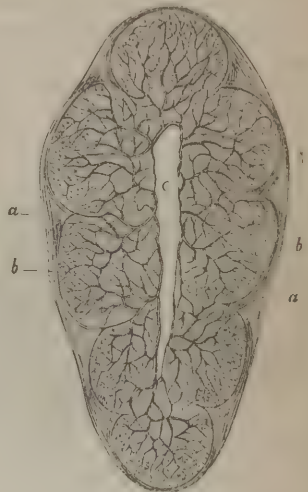
[1] Works, Sydenham Society's edit., p. 280, Lond., 1846.
[2] E. Wilson, System of Human Anatomy, 2d Amer. edit., p. 586, Philad., 1844.
[3] London and Edinburgh Monthly Journal of Medical Science, March, 1843.
[4] A Physiological Essay on the Thymus Gland, London, 1845.

organ exists through life, as each successive period of hibernation approaches, the thymus gradually enlarges, and becomes loaded with fat,

Fig. 502.

Section of Human Thymus, showing the large cavity in the wide portion and numerous orifices leading to its lobular cavities.

Fig. 503.



Transverse section through an injected lobule of the Thymus in a child.

a, Membranous investment of the lobule; *b*, membrane of the gland-granules; *c*, cavity of the lobule, from which the larger vessels branch out.

which accumulates in it, and in fat glands connected with it, in even larger proportion than it does in the adipous tissue; and, accordingly, it has been inferred, that it may serve for the storing up of materials to be reabsorbed during the hibernating period, which may maintain at that time the respiration and temperature of the body; or, to employ the language of Mr. Simon—"the gland fulfils its use as a sinking fund of nourishment in the service of respiration;"—and a similar view appears to be embraced by Professor Ecker of Basle.[1]

The *thyroid gland*, which has been described in another place,[2] and whose functions are equally obscure, is also largely developed in the fœtus; as well as the *supra-renal capsules.*

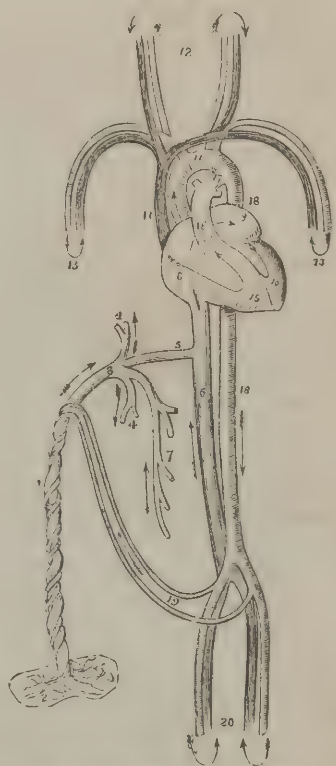
The *lungs*, not having received air in respiration, are collapsed and dense, of a dark colour, like liver, and do not fill the cavity of the chest. Their specific gravity is greater than that of water, and consequently they sink in that fluid. On cutting into them, no air is emitted, and no hemorrhage follows. The *absolute* weight is, however, less; no more blood being sent to them than is required for their nutrition; whilst, after respiration is established, the whole of the blood passes through them; the vessels are consequently filled with blood; enlarged, and the organs themselves increased in absolute weight. Ploucquet asserts, from experiments, that the mean weight

[1] Art. Blutgefässdrüsen, in Wagner's Handwörterbuch der Physiologie, 23ste Lieferung, S. 127, Leipzig, 1849.

[2] Vol. i. p. 243.

of the lungs of a full-grown fœtus, which never respired, is to that of the whole body as 1 to 70: whilst that of lungs in which respiration has been established is as 1 to 35, or doubled. These numbers cannot, however, be considered to afford a satisfactory average,—the exceptions being numerous; but they exhibit that, as might be expected, the absolute weight of the lungs is less, prior to the establishment of respiration. Careful and extended observations have satisfactorily shown, that although an increase in weight is generally found after respiration has been completely established, it is by no means the case when the inspirations have been feeble, as they often are for some hours and days after birth; and, on the other hand, it is not unusual to find, in infants that have not breathed, lungs as heavy as in the average of those that have. The subject is one of great interest as connected with infanticide; and has received much attention in the different modern works on Medical Jurisprudence.

Fig. 504.



Circulatory Organs of the Fœtus.

1. Umbilical cord. 3. Umbilical vein dividing into three branches: two (4 4) to be distributed to liver; and one (5), ductus venosus, which enters inferior vena cava (6). 7. Portal vein uniting with right hepatic branch. 8. Right auricle; course of blood denoted by arrow, proceeding from 8 to 9, left auricle. 10. Left ventricle: blood following arrow to arch of aorta (11). Arrows 12 and 13, represent return of blood from head and upper extremities through jugular and subclavian veins, to superior vena cava (14), to right auricle (8), and in course of arrow through right ventricle (15), to pulmonary artery (16). 17. Ductus arteriosus, the offsets at each side are right and left pulmonary artery cut off. Descending aorta (18, 18), umbilical arteries (19). external iliacs (20). Arrows at termination of these vessels mark return of venous blood by veins to inferior cava.

It is, however, in the *circulatory system* of the mature fœtus, that we meet with the most striking peculiarities. The heart is proportionably larger and more conical than in the adult. The *valve of Eustachius*—at the left side of the mouth of the inferior vena cava, where that vessel joins the sinus venosus —is larger than at an after period, and is supposed to direct the principal part of the blood of the ascending cava directly through the opening that exists between the right and left auricle. This opening, which is called *foramen ovale* or *foramen of Botal*, is in the septum between the auricles, and is nearly equal in size to the mouth of the inferior cava. It is situate obliquely; and has a membrane, forming a distinct valve, and somewhat of a crescentic shape, which allows part of the blood of the right auricle to pass through the opening into the left auricle, but prevents its return.

The pulmonary artery, instead of bifurcating as in the adult, divides

into three branches;—the right and left going to the lungs of the corresponding side, whilst the middle branch,—to which the name *ductus arteriosus* is given,—opens directly into the descending aorta; so that a great part of the blood of the pulmonary artery passes directly into that vessel. From the internal iliac arteries, two considerable vessels arise, called *umbilical arteries*. These mount by the sides of the bladder, on the outside of the peritoneum, and perforate the umbilicus in their progress to the umbilical cord and placenta. The *umbilical vein*, which is also a constituent of the cord, and conveys the blood from the placenta to the fœtus, arises from the substance of the placenta by a multitude of radicles, which unite together to form it. Its size is considerable. It enters the umbilicus, passes towards the inferior surface of the liver, and joins the left branch of the vena porta hepatica. Here a vessel exists called *ductus venosus*, which opens into the vena cava inferior, or joins the left vena hepatica where that vein enters the cava. A part only of the blood of the umbilical vein goes directly to the vena cava; the remainder is distributed to the right and left lobes of the liver, especially to the latter.

The *digestive apparatus* exhibits few peculiarities. The bowels, at the full period, always contain a quantity of greenish, or deep black, viscid fæces, to which the term *meconium* has been applied, owing to their resemblance to the inspissated juice of the poppy (μηκων, "a poppy"). It appears to be a compound of the secretions from the intestinal canal and bile, and frequently contains down or fine hairs mixed with it. It has been analyzed by Dr. John Davy,[1] and found to consist of:—

Mucus and epithelium scales,	23·6
Cholesterin (in plates) and margarin,	·7
Colouring and sapid matter of bile, and olein,	3·0
Water,	72·7
	100·0

Its ashes contained peroxide of iron and magnesia, with a trace of phosphate of lime and chloride of sodium. An analysis by Simon[2] also exhibits that it contains the main constituents of bile:—

Cholesterin,	16·00
Extractive matter and bilifellinic acid,	14·00
Casein,	34·00
Bilifellinic acid and bilin,	6·00
Biliverdin with bilifellinic acid,	4.00
Cells, mucus, albumen,	26·00
	100·00

Frerichs[3] found it to yield on analysis:—

Biliary resin,	15·6
Cholesterin, olein, and margarin,	15·4
Epithelium, mucus, pigment, and salts,	69·
	100·

The *liver* is very large; so much so as to occupy both hypochondriac regions; and the right and left lobes are more nearly of a size than in

[1] Medico-Chirurgical Transactions, xxvii. 189, Lond., 1844.
[2] Animal Chemistry, Sydenham Society's edition, ii. 367, Lond., 1846.
[3] Kirkes and Paget, Manual of Physiology, 2d Amer. edit., p. 198, (note,) Philad., 1853.

the adult. Prior to birth it would seem to be the only decarbonizing organ, the lungs being inactive; but as soon as respiration is established, less blood is sent to the liver; and this diminution takes place with great rapidity, and is usually evidenced a short time after birth by the comparative paleness of its substance. Hence it has been supposed, that the weight of the liver might aid in the determination of the question, whether a child had breathed or not. It has been shown, however, that although the liver, as a general rule, weighs less after respiration has been established, it is by no means the case when the inspiration has been feeble for hours or days after birth; and, on the other hand, it is not uncommon to meet, in infants that have not breathed, with livers as light as in the average of those that have. In the small intestine and the hepatic ducts an albuminous fluid has been found by Drs. Prout and Robert Lee,[1] which seemed to them to be separated from the blood, carried from the placenta to the liver, and to be indirectly inservient to the nutrition of the fœtus. Dr. George Robinson[2] also invariably found in the stomach of the fœtus, during the latter period of its uterine existence, a peculiar substance, differing from the liquor amnii, and generally of a nutritious character, which he regards as the secretion of the salivary glands. The mixture of this substance with the liquor amnii is, he considers, the material submitted to the process of chymification in the fœtal intestines.

The *urinary bladder* is of an elongated shape, and extends almost to the umbilicus. The muscular coat is somewhat thicker and more irritable than in the adult, and it continues to possess more proportionate power during youth. The common trick of the schoolboy—of sending a jet of urine over his head—is generally impracticable in more advanced life. From the fundus of the bladder, a ligament of a conical shape, called *urachus*, ascends between the umbilical arteries to the umbilicus; becoming confounded there with the abdominal aponeuroses, according to Bichat; and forming a kind of suspensory ligament to the bladder. It is sometimes found hollow in the human fœtus, but Bichat considers such a formation to be preternatural. In the fœtal quadruped, it is a large canal, which transmits urine to the *allantois*, of which, as well as of other fœtal peculiarities, we have previously treated.[3]

From examinations of the fœtal urine, made by Dr. William D. Moore,[4] he concludes—admitting, however, that the subject has as yet been most imperfectly dealt with—that it would appear to be an albuminous fluid, of feeble reaction, free from sugar, containing some of the usual salts of the urine, abounding in a highly nitrogenized principle, probably allantoin, but affording no urea, and depositing a most remarkably large amount of nucleated epithelium.

Lastly, the *genital organs* of the fœtus require notice. The successive developement of this part of the system has given rise to some singular views regarding the cause of sex. During the first few

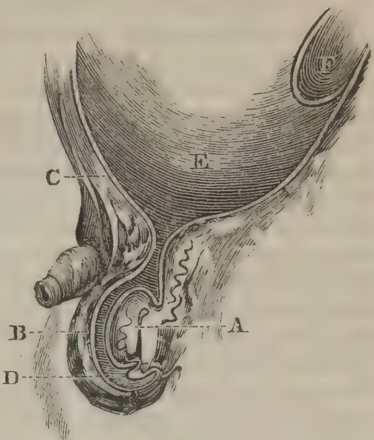
[1] Lectures on the Theory and Practice of Midwifery, Amer. edit., p. 145, Philad., 1844.
[2] London and Edinburgh Monthly Journal of Medical Science, Jan., 1847, p. 507.
[3] Page 537.
[4] Dublin Quarterly Journal of Medical Science, August, 1855, p. 88.

weeks, the organs are not perceptible; but, about the termination of the fifth, a small cleft eminence appears, which is the rudiment of the scrotum, or of the vulva, according to the sex. In the sixth week, an aperture is perceptible, common to the anus and genital organs, in front of which is a projecting tubercle. In the seventh and eighth weeks, this tubercle seems to be tipped by a glans, and grooved beneath by a channel which extends to the anus. In the eleventh and twelfth, the perineum is formed and separates the anus from the genital organs. In the fourteenth the sex is distinct; but there still remains, for some time, a groove beneath the clitoris or penis, which becomes closed in the former, and made into a canal in the latter. This striking similarity between the male and female organs has led Tiedemann[1] to conclude, that the female sex is the male arrested at an inferior point of organization. In his view, every embryo is originally female; the cleft, described above, being the vulva,—the tubercle, the clitoris: to constitute the male sex, the cleft is united so as to form a raphe; the labia majora are joined to form the scrotum; the nymphæ to form the urethra, and the clitoris is transmuted into a penis. In support of this opinion, he asserts, that the lowest species of animals are almost all females; and that all the young acephali and aborted fœtuses, which have been examined, are of that sex. Others, again, assert, that the sexes are originally neuter, and that the future sex is determined by accidental circumstances during the first week of fœtal life; whilst M. Velpeau is disposed to believe, that they are all male—the infrapubic prolongation existing in every embryo, although there may be neither labia majora nor scrotum. Admitting, however, that the embryo belongs to either the one or the other sex, or is neutral, we must still remain at a loss regarding the influences that occasion the subsequent mutations; and it seems impossible not to admit, that although an apparent sexual identity may exist among different embryos, there must be an instinct or force of impulsion seated somewhere, which gives occasion to the sex being ultimately male or female, in the same manner as it causes the young being to resemble one or other parent in its external or internal configuration; and if our means of observation were adequate to the purpose, a distribution of arteries or nerves might perhaps be detected, which could satisfactorily account *ab initio* for the resulting sex. In the absence of such positive data, M. Geoffroy St. Hilaire has hypothetically suggested, that the difference of sex may be owing to the distribution of the two branches of the spermatic artery. If they continue in approximation, proceeding together,—the one to the testicle, the other to the epididymis,—the individual is male; if they separate,—the one going to the ovary, the other to the cornua of the uterus,—the individual is female. The degree of predominance of the cerebro-spinal system, he thinks, determines the approximation or separation of the two arterial branches. This predominance being greater in the male, the spermatic arteries are more feeble, and consequently in greater proximity; and conversely in the female;[2] but this suggestion does not remove the obscurity.

[1] Anatomie der Kopflosen Missgeburten, S. 54, Landshut, 1813.
[2] Adelon, Physiologie de l'Homme, 2de édit., iv. 375.

Leaving these phantasies of the generalizing anatomists on a subject regarding which we must, probably, ever remain in the dark, let us inquire into the phenomena of the *descent of the testes* in the fœtus. In the early months of fœtal life, the testicle is an abdominal viscus, seated below the kidney. About the middle of the third month, it is about two lines long, and situate behind the peritoneum, which is reflected over its ventral surface. At this time, a sheath of peritoneum may be observed, passing from the abdominal ring to the lower part of the testicle, and containing a ligament, called by Mr. Hunter, who first described it, *gubernaculum testis*, which generally has been considered to be formed of elastic areolar tissue, proceeding from the upper part of the scrotum, and from the part of the general aponeurosis of the thigh near the ring.

Fig. 505.



Descent of the Testicle.

A. Testicle in scrotum. B. Prolongation of peritoneum. C. Peritoneum lining abdomen. D. Peritoneum forming tunica vaginalis. E. Cavity of peritoneum. F. Kidney.

Mr. Curling[1] describes it as surrounded by a thin layer of striped

Fig. 506.

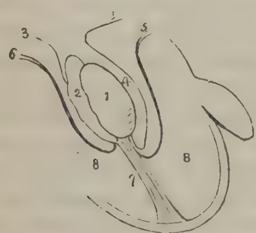


Fig. 507.

Diagrams illustrating the descent of the Testis.

Fig. 506. 1. The testis. 2. The epididymis. 3, 3. The peritoneum. 4. The pouch formed around the testis by the peritoneum. 5. The pubic portion of the cremaster attached to the lower part of the testis. 6. The portion of the cremaster attached to Poupart's ligament. The mode of eversion of the cremaster is shown by these lines. 7. The gubernaculum, attached to the bottom of the scrotum, and becoming shortened by the contraction of the muscular fibres which surround it. 8, 8. The cavity of the scrotum. 9. The peritoneal cavity.

Fig. 507. In this Figure the Testis has completed its descent. The Gubernaculum is shortened to its utmost, and the Cremaster is completely everted. The pouch of Peritoneum above the Testis is compressed so as to form a Tubular Canal.

1. A dotted line marks the point at which the tunica vaginalis will terminate superiorly; and figure 2 its cavity. 3. The peritoneal cavity.

muscular fibres, the cremaster, which pass upwards to be attached to the testis; inferiorly the fibres having the same attachments as the

[1] Lond. Lancet, April 10, 1841, p. 70; Practical Treatise on the Diseases of the Testis, p. 32, Lond., 1843, 2d Amer. edit., Philad., 1856; and Art. Testicle, Cyclopædia of Anatomy and Physiology, Pt. xxxviii. p. 982. February, 1850.

cremaster, and being in reality the cremaster inverted. The descent of the testis is effected by the traction of these fibres. During the descent, "the muscle of the testis is gradually everted, until, when the transition is completed, it forms a muscular envelope external to the process of peritoneum, which surrounds the gland and the front of the cord." Prof. E. H. Weber[1] has a similar view. He affirms, as the result of experiments on man, rabbits, and beavers, that the gubernaculum originates in the form of a sac in the situation of the inguinal canal. The lower end of this sac extends to the bottom of the scrotum, the upper end extends through the internal abdominal ring as high as the testis, carrying up along with it, to the fold by which that organ is suspended, fibres from the internal oblique muscle. By the aid of the contraction of these fibres, a kind of inversion (Einstülpung) or intussusception of the hollow gubernaculum is induced. Kölliker,[2] too, describes the gubernaculum as a process composed of transversely striated and smooth muscles.

The head of the fœtus in utero being the lowest part, the testis has necessarily to ascend into the scrotum, and consequently some force must be exerted upon it. This is supposed to be effected by the contraction of the gubernaculum testis. About the seventh month, the testes are in progress towards the scrotum, and have attained the inner ring. In this descent, the organ abandons successively one portion of the peritoneum to pass behind another immediately below, until the lowest part of the pouch, formed by the peritoneum, around the testicle as in Figs. 505–6–7, becomes the tunica vaginalis testis; whilst the portion of peritoneum, that descended before the testicle, becomes, when the testicle has fully descended, the second coat or tunica vaginalis.

As soon as the testicle has reached the lower part of the scrotum, the neck of the pouch approaches a closure, and this is commonly effected at birth. Sometimes, however, it remains open for a time; the intestines pass down, and congenital hernia is thus induced.

The testes have not always descended into the scrotum at birth, even at the full period; of 97 new-born infants, Wrisberg found both of them in the scrotum in 67: one or both in the canal in 17; one testis in the abdomen in 8; and both in the abdomen in 3.[3] Sometimes, as has been remarked elsewhere, one or both testes remain through life in the abdomen, a condition which is natural in the ram.

2. PHYSIOLOGY OF THE FŒTUS.

In investigating this interesting point of human physiology, we shall inquire into the functions, in the order adopted respecting the functions of the adult. On many of the topics that will have to engage attention, it will be found that the deepest obscurity rests, whilst the hypotheses indulged regarding them have been of the most fanciful and mystic character.

[1] Müller's Archiv. für Anatomie u. s. w. H. v., s. 403, Jahrgang, 1847.

[2] Mikroskopische Anatomie, ii. 420, Leipz., 1854; and Sydenham Society's edit. of his Manual of Histology, Amer. edit., p. 635, Philad., 1854.

[3] Comment. Soc. Reg. Scient., Gotting., 1778.

a. *Functions of Nutrition.*

These functions are not as numerous in the fœtus as in the adult. Their object is, however, the same,—the formation of the various parts of the organized machine, and their constant decomposition and renovation.

One of the least tenable hypotheses, that have been entertained regarding the embryo at its first formation is,—that, for the first month —and why the period is thus limited is not apparent—the vitality of the fœtus is not independent, but is a part,—an offset, as it were,—of that of the mother; that it has no separate powers of existence; no faculty of self-evolution; and that its organs are nourished by the plastic materials, which it incessantly derives from the maternal blood. It appears manifest, that from the very moment of the union of materials furnished by both sexes at a fecundating copulation, the elements of the new being must exist; and that it must possess, within itself, the faculty of self-evolution; otherwise, how can we understand the phenomena, that take place in the ovary after fecundation. It is admitted, that this organ furnishes the unfecundated ovum; and that the sperm must come in contact with it; after which, fecundation is accomplished, and immediately the ovum undergoes a farther developement; escapes, in due time from the viscus in which it was formed; is laid hold of by the Fallopian tube; passes through that canal, and is deposited in the interior of the uterus, with which it ultimately contracts adhesions. But all this requires time. The ovum does not probably reach the uterus, in the human female, before ten or twelve days; and some time must still elapse before such adhesions are effected; and, consequently, before anything like maternal blood, whence the plastic materials are derived, according to the view in question, could be sent to it. During this time, the embryo must derive its nourishment from the nutritious matters with which it is surrounded in the ovum, in the same manner as the young of the oviparous animal, during incubation, obtains the nutriment necessary for its full developement from the matters surrounding it.

The albuminous and oily contents of the ovum, surrounding the embryo of the oviparous animal, would seem to resemble greatly the milk of the mammalia both physically and chemically, and M. Joly[1] has suggested the following points of similarity. "The milk is composed essentially of fatty matter—butter, suspended under the form of globules in an albuminoid fluid—casein; and it contains water, sugar of milk, and salts; amongst others, phosphate of lime, so eminently useful for the consolidation of the bones of the young being that feeds upon it. In the egg there are vitelline globules, which contain a fat oil, susceptible of congelation on cooling,—evidently the *analogue* of butter and the globules that contain it. In the egg are, likewise, albumen, and *vitelline*, which is a very slight modification of it. Now, it is admitted by chemists, that albumen, vitelline, animal protein and animal fibrin differ so little from casein, that all these substances may be, and in fact are, confounded under the common denomination of

[1] Comptes Rendus, No. 20, 12 Novembre, 1849, p. 524.

albuminoid or proteiform matters. Moreover, Winckler, Barreswil, and, quite recently, M. Braconnot, from whom I have learned this interesting fact, have discovered sugar of milk in eggs; and every one is aware that, as in the milk itself, water and salts are found and particularly phosphate of lime. It may be added, that on treating the hen's egg like the milk of the mammalia, and by the same chemical agents (alcohol, sulphuric ether, and acetic acid), I have obtained almost the same reactions."

In due time, after the ovum has reached the interior of the uterus, it is compelled to absorb appropriate nutriment from the mother;—the minute quantity existing in the ovum, at this early period, being insufficient for the developement which it is destined to attain. In this last respect, the human ovum differs from the egg of an oviparous bird, which is hatched out of the body, and contains sufficient nutriment for full fœtal evolution. In treating of this subject, Dr. Granville[1] has the following remarks.—"What stronger proof need be required of the existence of an adherent life principle in the ovulum, which is, at one time at least,—indeed, I suspect throughout the period of gestation,—independent of any connexion with the parent mother? Yet none of the earlier writers who adopted the ovarian theory of generation have ever asked themselves this question:—what supports the vitality of a fecundated ovulum after it has left the ovarium, and previously to its becoming connected with the womb? In fact, the subject had never been mooted, before the more modern physiologists took it up and satisfactorily explained it:"—and he adds in a note:—"the whole of the English physiologists, writers on midwifery, and lecturers, whether ancient or modern, are entirely silent on this important stage of embryonic life." It is a topic, however, discussed at length in the first edition of this work, which was published before that of Dr. Granville, and is much expanded in the subsequent editions.[2]

Since the time of Hippocrates, Aristotle, and Galen, different anatomists and physiologists have asserted, that the umbilical vein is the only channel through which nutriment reaches the fœtus; in other words, that the whole of the nourishment which it receives is from the placenta; but the facts, to which allusion has already been made, are sufficient to overturn this hypothesis. It is impossible, that the placenta can have any agency until it is *in esse*. Such an explanation of the process of fœtal nutrition could only hold good after the first periods, and then, as we shall see, it is sufficiently doubtful. Accordingly, some of the most distinguished modern physiologists, who have devoted their attention to embryology, have completely abandoned the idea of placental agency during the first months; and they, who have invoked it at all, have usually done so as regards the after periods only. On all this subject, however, we have the greatest diversity of views. Lobstein,[3] for example, affirms, that the venous radicles of the rudimental placenta obtain nutritive fluids from the mother during the first days only, until the period when the arteries are formed; but that, after this, all circulation between the uterus and placenta ceases,

[1] Graphic Illustrations of Abortion, p. vii., Lond., 1834.
[2] Human Physiology, 1st edit., ii. 365, Philad., 1832.
[3] Essai sur la Nutrition du Fœtus. Strasbourg, 1802.

and the fluid of the umbilical vesicle, the liquor amnii, and the jelly of the cord, are the materials of nutrition. Meckel[1] thinks the placenta is never the source of nutritive materials. He regards it as an organ for the vivification of the blood of the fœtus, analogous to the organ of respiration in the adult; and nutrition is, in his opinion, accomplished by the matter of the umbilical vesicle in the beginning, by the liquor amnii until midterm, and by the jelly of the cord until the end. According to M. Béclard,[2] nutrition is effected, during the first weeks, by the fluid of the umbilical vesicle; afterwards, by the liquor amnii, and the jelly of the cord; and as soon as the ovum becomes villous, and developes the placenta, by that organ. Dr. Montgomery[3] has described several "decidual cotyledons," as he terms them, which are best seen about the second or third month, and are not to be found at the advanced period of gestation. These are small cup-like elevations on the external surface of the decidua uteri, having the appearance of little bags, the bottoms of which are attached to, or embedded in, its substance; they then expand a little, and again grow smaller towards their outer or uterine end, which, in by far the greater number of them, is an open mouth when separated from the uterus: how it may be when adherent he does not profess to say, nor does he offer any decided opinion as to their precise nature or uses; but, from having on more than one occasion observed within their cavity a milky or chylous fluid, he is disposed to consider them reservoirs for nutrient fluids separated from the maternal blood, to be thence absorbed for the support and developement of the ovum. "This view," says Dr. Montgomery, "seems strengthened when we consider, that at the early periods of gestation, the ovum derives all its support by imbibition, through the connexion existing between the decidua and the villous processes covering the outer surface of the chorion." M. Adelon[4] is of opinion, that two sources of nutrition ought alone to be admitted,—the umbilical vesicle, which is the sole agent for nearly two months, and the placenta for the remainder of the period. M. Velpeau[5] equally thinks, that the nutriment of the ovum is derived from different sources at different periods of intra-uterine existence. The embryo, he says, is at first but a vegetable, imbibing the surrounding humours. The villi of its circumference, which are true cellular *spongioles*, obtain nutritive principles in the Fallopian tube and the uterus, to keep up the developement of the vesicles of the embryo; after which the new being is nourished like the chick in *ovo*, or rather like the plantule, which is, at first, altogether developed at the expense of principles enclosed in its cotyledons. It gradually exhausts the vitelline substance contained in the umbilical vesicle. The emulsive substance of the reticulated sac of the allantoid pouch is also gradually absorbed. The end of the second month arrives; the vessels of the cord are formed, and the placenta is developed; by its contact with the uterus, this organ obtains

[1] Handbuch, u. s. w., Jourdan and Breschet's French translation, iii. 1784.
[2] Embryologie ou Essai Anatomique sur le Fétus Humain, Paris, 1821.
[3] Signs and Symptoms of Pregnancy, p. 133, Lond., 1837.
[4] Physiologie de l'Homme, 2de édit., iv. 397, Paris, 1829.
[5] Embryologie ou Ovologie, &c., Paris, 1833; and Traité Elémentaire de l'Art des Accouchemens, Professor Meigs's translation, 2d edit., p. 213, Philad., 1838.

reparatory materials; elaborates them; and forms from them a fluid more or less analogous to blood, which fluid is absorbed by the radicles of the umbilical vein.

The views of Professor Goodsir on this subject have been referred to already.[1]

We find, consequently, some of the most distinguished physiologists denying—as it would seem that every one ought to do—that the nutrition of the fœtus takes place solely from blood sent by the mother to the fœtus. If we search into the evidence afforded by transcendental anatomy, we find that amidst the various singular monstrosities met with, there would appear to be but one thing absolutely necessary for fœtal developement,—an absorbing surface, surrounded by a nutritive substance, capable of being absorbed. Head and heart may be wanting, and yet the fœtus may grow so as to attain its ordinary dimensions. We have the most incontestable evidence, that neither the placenta nor umbilical cord is indispensably necessary for fœtal developement. M. Adelon disposes of this in the most summary manner, by affirming, that "there is no authentic instance of a fœtus, devoid of umbilical cord and placenta, attaining full uterine growth." The case is not, however, got rid of so easily. Marsupial and monotrematous animals are non-placental, or breed their young without either positive placenta or cord. The embryos are enclosed in one or more membranes, which are not attached to the coats of the uterus, and they are supplied with nourishment from a gelatinous matter by which they are surrounded. Thomas Bartholin, during his travels in Italy, saw an individual, forty years old, who was born without anus, penis, or umbilicus; and M. Velpeau cites similar cases from Ruysch, Samson, Chatton, Rommeil, Denys, Fatio, V. Geuns, Sue, Penchienati, Franzio, Desgranges, Kluyskens, Pinel, Mason, Osiander, Dietrich, Von Froriep, and Voisin; but as these cases militate against his views of embryotrophy, he attempts to diminish their force by affirming, that the observations, which he had made, satisfy him, that all the fœtuses thus born had died in utero, in consequence of the destruction of the cord, or the closure of the umbilicus; or else, that the umbilicus existed, but was hidden or lost in the extroversion of the bladder almost always remarked in those that lived. Passing by the singular deduction of M. Velpeau, that his observations have satisfied him of the incorrectness of those made by observers, many of whom have long since left the stage,—long before he existed,—as well as the facts relating to the marsupial animal, and that the fœtus, in extra-uterine pregnancies, has frequently no placenta,—with the case cited by Dr. Good, from Hoffmann, of a fœtus born in good health and vigour, the funis sphacelated and divided into two parts; and one by Stalpart Van der Wiel,[2] of a living child, exhibited without any umbilicus as a public curiosity,—a case observed by Dr. Good[3] himself, appears to be unanswerable. The case in question occurred in 1791. The labour was natural; the child, scarcely less than the ordinary size, was born alive; cried feebly

[1] Pages 552, 557.
[2] Observat. Rar. Med.-Chirurg., cent. ii., p. 1, Obs. 32.
[3] Case of Preternatural Fœtation with Observations, read before the Medical Society of London, Oct. 20, 1794; and Study of Medicine, in Physiological Proem to Class v. Genetica.

once or twice after birth, and died in about ten minutes. The organization, both internal and external, was imperfect in many parts. There was no sexual character; neither penis nor pudendum; nor any internal organ of generation. There was no anus, no rectum, no funis, no umbilicus. The minutest investigation could not discover the least trace of any. With the use of a little force, a small, shrivelled placenta,—or rather the rudiment of a placenta,—followed soon after the birth of the child, without funis or umbilical vessels of any kind, or any appendage by which it appeared to have been attached to the child. In a quarter of an hour afterwards, a second living child was protruded into the vagina and delivered with ease, being a perfect boy, attached to its placenta by a proper funis. The body of the first child was dissected in the presence of Dr. Drake of Hadleigh, and of Mr. Anderson of Sunbury, to both of whom Dr. Good appeals for the correctness of his statement. In the stomach, a liquor was found resembling liquor amnii.

How could nutrition have been effected, then, in this case? Certainly not by blood sent from the mother to the child, for no apparatus for its conveyance was discoverable; and are we not driven to the necessity of supposing, that nutriment must have been obtained from the fluid within the ovum? This case,—with the arguments already adduced,—seems to constrain us to admit, that the liquor amnii may have more agency in the nutrition of the new being than is generally granted. Professor Monro,[1] amongst other reasons,—all of which are of a negative character,—for his disbelief in this function of the liquor amnii, asserts, that if the office of the placenta be not that of affording food to the embryo, it becomes those, who maintain the contrary doctrine, to determine what other office can be allotted to it; and that till this is done it is more consistent with reason to doubt the few and unsatisfactory cases, at the time brought forward, than to perplex ourselves with facts directly contradictory of each other. The case given by Dr. Good, since Professor Monro's remarks were published, is so unanswerable, and so unquestionable, that it affords a positive fact of full, or nearly full, fœtal developement, independently of placenta and umbilical cord; and the fact must remain, although our ignorance of the functions of the placenta may be "dark as Erebus."[2]

[1] Edinburgh Medical Essays, ii. 102.

[2] The following case, with which the author was obligingly favoured by his friend, Dr. Wright, of Baltimore, has an instructive bearing upon the subject. The condition of the placenta was such as to lead that intelligent observer to conclude, that any circulation between the mother and the fœtus, through the placenta, was impracticable.

"*Baltimore*, September 26th, 1835.

"Dear Sir,—In compliance with your request, I offer you the following plain and short statement of a case, which occurred in my practice, at the date indicated.

"On the 6th of December, 1833, I was requested to visit Mrs. T——, of this city,—a young woman of large frame, good constitution, and generally excellent health. She had been married about fifteen months, and I was now called to attend her first labour. She had felt occasional labour pains through the day, and was delivered of a fine, vigorous female infant, in about four hours from the time of my call. The labour was, in all respects, natural, and as easy as is common—or consistent—with a first parturition. After the birth of the child, an hour, perhaps, was passed in waiting for secondary pains to effect the expulsion or favour the removal of the placenta, but no movement of this kind having then occurred, a gentle examination was made to ascertain

That the liquor amnii is possessed of nutritive properties is shown not only by its containing albumen, and, it is said, osmazome; and by the fact, that new-born calves have been nourished for a fortnight on fresh liquor amnii;[1] but amongst those physiologists, who admit it to be a fluid destined for fœtal nutrition, a difference prevails regarding the mode in which it is received into the system. Osiander,[2] Brugmans,[3] Van den Bosch, Fohmann, Carus,[4] and others, think it is absorbed through the skin. In the fœtal state, the cuticle is extremely thin, and, until within a month or two of the full period, can be scarcely said to exist. There is not, consequently, that impediment to cutaneous absorption which, we have seen, exists in the adult. The strong argument, however, which they offer in favour of such absorption is the fact, that the fœtus has been developed, although devoid of both mouth and umbilical cord; and Professor Monro, in opposing this function as-

whether that body might be easily and properly taken away. The vagina contained nothing more than the funis—the outlet of the uterus was open, soft and extensible. The cord was gently followed into the uterine cavity, and the cake found near its fundus, retaining a close connexion with the uterus. The placental mass was large and firm, presenting to the touch a peculiar feeling—as of a dense sponge, full of coarse, granular or gravelly particles. Deeming it now proper to relieve the patient fully, a cautious effort was made to detach the placenta from the uterus, in order to its manual extraction. In pursuing this design, it was found, that the adhering surface of the former consisted of a uniform calcareous lamina or plate, rough to the finger, and exciting such a sensation or feeling as would be caused by a sheet of coarse sand-paper. When the mass was detached, and brought away, the laminar surface, just referred to, was found to be a calcareous plate, uniformly covering the whole of the attached portion of the cake,—the entire surface of the utero-placental connexion. The calcareous matter, thus distributed, was thin, and readily friable, but, as before remarked, it appeared to constitute a uniform and superficial covering. The correspondent uterine surface—the part from which the placenta had been separated—felt rough, but comparatively soft, imparting nothing distinctly of the calcareous or gritty feel. Out of the body, the placenta felt heavy, and eminently rough throughout. When compressed or rubbed together, the large amount of nodular or granular matter, dispersed through its substance, was not only manifest to the touch, but a very audible crepitation or grating sound could be thus elicited from any and every part of the mass.

"In this uncommon instance of placental degeneracy, both the mother and child were perfectly healthy and well. The latter, indeed, was remarkable for its fine size, perfect nutrition and vigour. From the condition of the cake, and the character of its adhesion to the uterus, I apprehended a more than ordinary liability to secondary affection, in the form of puerperal fever,—and whether influenced or not by the circumstances detailed, secondary fever did ensue on the third day from delivery, attended by the usual signs of puerperal hysteritis, which affection, however, was happily subdued by general and topical bleeding, calomel, &c.

"With sincere regard, yours,

"T. H. Wright.

"Professor Dunglison.

"P. S.—The child, referred to, is living, and, from its birth to the present, has considerably exceeded the common bulk of children at the same age. The mother is now far advanced in her second pregnancy."

After this letter was written, the same lady was delivered of another healthy child. The maternal surface of the placenta was of the like calcareous character; but the deposition was not to the same extent as in the first pregnancy. A similar case has been described by Mr. Gilbert, of Beaminster, England.*

[1] Cazeaux, Traité Théorique et Pratique de l'Art des Accouchements, p. 176, Paris, 1840.

[2] Handbuch der Entbindungskunde, B. i., S. 237.

[3] De Naturâ et Utilitate Liquoris Amnii, Ultraject., 1792.

[4] Lehrbuch der Gynäkologie, Th. ii., S. 27, Leipz., 1828.

* Lancet, for Dec. 16, 1837, p. 418.

cribed to the liquor amnii, refers to cases of monstrous formation, in which no mouth existed, nor any kind of passage leading to the stomach. Others, as Haller[1] and Darwin,[2] are of opinion, that the fluid enters the mouth and is sent on into the stomach and intestines; and in support of this view they affirm, that the liquor amnii has been met with in these organs. Heister, on opening a gravid cow that had perished from cold, found the liquor amnii frozen, and a continuous mass of ice extending to the stomach of the fœtus.[3] Observations, by Dr. George Robinson,[4] on fœtal animals more especially, have led him to affirm, that in the earlier stages of the developement of the fœtus, the contents of the stomach consist chiefly of liquor amnii, to which a peculiar matter is added, which—as before remarked—he refers to the salivary glands. He states, moreover, that the liquor amnii continues to be swallowed until birth, and the mixture of this with the peculiar salivary secretions is the material subjected to chymification; yet he ascribes the main agency in fœtal nutrition, in the later months, to the "placental vessels."

Physiologists who believe, that the liquor amnii is received into the stomach, differ as to what happens to it in that organ. Some suppose, that it is simply absorbed without undergoing digestion; others, that it must be first subjected to that process. According to the former opinion, it is simply necessary, that the fluid should come in contact with the mucous membrane of the alimentary passages; and they affirm, that if digestion occurs at all, it can only be during the latter months. Others, however, conceive, that the waters are swallowed or sucked in, and undergo true digestion. In evidence of this they adduce the fact of meconium existing at an early period in the intestinal canal, which they look upon as evidence that the digestive function is in action; and, in further proof, they affirm, that on opening the abdomen of a new-born infant the chyliferous vessels were found filled with chyle, which could not, they say, have been formed from any other substance than the liquor amnii; and lastly, that fine silky down has been found in the meconium, similar to that which exists on the skin of the fœtus, and which is conceived to have entered the mouth along with the liquor amnii. These reasons have their weight, but they cannot explain the developement in the cases above alluded to, in which there was no mouth; and of course cannot apply to the acephalous fœtus. Moreover, it has been properly remarked, that the presence of meconium in the intestinal canal—admitting that it is the product of digestion, which is denied by many—merely proves, that digestion has taken place, and the same may be said of the chyle in the chyliferous vessels: neither one nor the other is a positive evidence of digestion of the liquor amnii. Both might have proceeded from the stomachal secretions. It has also been affirmed, that meconium exists in the intestines of the acephalous fœtus; and in those in which the mouth is imperforate. Lastly, with regard to the down discovered in the meconium, it has been suggested as possible, that it may be formed by

[1] Elementa Physiologiæ, viii. 205. [2] Zoonomia, vol. ii. p. 203, London, 1801.
[3] Adelon, Physiologie de l'Homme, iv. 389, Paris, 1829.
[4] London and Edinburgh Monthly Journal of Medical Science, Jan., 1847, p. 512.

the mucous membrane of the intestine, which so strongly resembles the skin in structure and functions.

Others have supposed, that the liquor amnii is received through the respiratory passages, from the circumstance, that in certain cases the fluid has been found in the trachea and bronchia;—some presuming, that it readily and spontaneously enters the nostrils and passes to the trachea and bronchia; others, that it is forced in by the pressure of the uterus; and others, again, that it is introduced by the respiratory movements of the fœtus. Views have differed in this case, also, regarding the action exerted upon it after introduction; some presuming that it is absorbed immediately; others, that it is inservient to a kind of respiration; and that, during fœtal existence, we are aquatic animals, —consuming the oxygen or atmospheric air, which Scheele,[1] Lassaigne,[2] and others have stated to exist in it. It is scarcely necessary to oppose these gratuitous speculations seriously. The whole arrangement of the vascular system of the fœtus, so different from that which is subsequently established, and the great diversity in the lungs, prior and subsequent to respiration, would be sufficient to refute the idea,—had it even been shown, that the liquor amnii always contains one or other of these gases, which is by no means the fact. The case of the acephalous fœtus is likewise an obstacle to this view as strong as to that of the digestion of the liquor amnii.

As if to confirm the remark of Cicero—"nihil tam absurdum, quod non dictum sit ab aliquo philosophorum,"—it has been advanced by two individuals of no mean pretensions to science, that the liquor amnii may be absorbed by the genital organs, or by the mammæ. Lobstein[3] supports the former view; Oken[4] the latter. Oken asserts, that the fluid is received by the mammæ, elaborated by them, and thence conveyed into the thymus gland, the thoracic duct, and the vascular system of the fœtus. Hence, the necessity of both sexes possessing nipples before birth. Of these various opinions, the one that assigns the introduction of the fluid to the agency of the cutaneous absorbents appears to carry with it the greatest probability. It must be admitted, however, that the whole subject is in obscurity, and requires fresh, repeated, and accurate experiments and observations. But it may be asked, with Dr. Monro, what are the nutritive functions performed by the placenta? We have before alluded to the different views entertained regarding the connexion between the placenta and the uterus. Formerly, it was universally maintained, that vessels pass between the mother and the maternal side of the placenta, and that others pass between the fœtus and the fœtal side, but that the two sides are so distinct, as to justify their being regarded as two placentæ,—the one maternal, the other fœtal,—simply united to each other. At one time, again, it was supposed, that a direct communication exists between the maternal and fœtal vessels, but this notion has long been exploded. We have decisive evidence, that the connexion is of the most indirect nature. Wrisberg made several experiments, which showed, that the

[1] De Liquoris Amnii Utilitate, Copenhag., 1795.
[2] Archiv. Général. de Méd., ii. 308.
[3] Essai sur la Nutrition du Fœtus, p. 102, Strasbourg, 1802.
[4] Zeugung, p. 162, Bamberg, 1805.

circulatory apparatus of the fœtus is not drained when the mother dies of hemorrhage. It has been affirmed, too, that if the uterine arteries be injected, the matter of the injection passes into the uterine veins, after having been effused into the lobes of the placenta. If, on the other hand, the injection be thrown into the umbilical arteries it passes into the umbilical vein, and is effused into the placenta, but does not enter the uterine vessels. When, however, an odorous substance, like camphor, is injected into the maternal veins of an animal, the fœtal blood ultimately assumes a camphorated odour; when animals have been fed on madder during gestation, the colouring matter has been found in the fœtus;[1] and, when the human female has taken rhubarb, evidence of it has been found in the liquor amnii, in the serum of the blood of the umbilical vessels, and in the first urine of the infant.[2] M. Magendie[3] injected this substance into the veins of a gravid bitch, and extracted a fœtus from the uterus at the expiration of three or four minutes; the blood did not exhibit the slightest odour of camphor; whilst that of a second fœtus, extracted at the end of a quarter of an hour, exhibited it decidedly. Such was the case, also, with the other fœtuses. The communication may, however, have been owing to the same kind of transudation and imbibition, of which we have spoken under the head of Absorption, and might, consequently, be regarded as entirely adventitious; and the fact of the length of time required for the detection of the odorous substance favours the idea; for if any direct communication existed between the mother and fœtus, the transmission ought certainly to have been effected more speedily. The transmission of substances from the fœtal to the maternal placenta is still more difficult. M. Magendie was never able to affect the mother by poisons injected into the umbilical arteries, and directed towards the placenta; and he remarks, in confirmation of the results of the experiments of Wrisberg, that if the mother dies of hemorrhage, the vessels of the fœtus remain filled with blood. They who consider, that there is no maternal and fœtal portion of the placenta, or, rather, that it is all fœtal, of course believe, where the matter of injection, thrown into the uterine vessels, has passed into the cells of the placenta, that it has been owing to the rupture of parts by the force with which the injection has been propelled.

Another fact, which proves the indirect nature of the connexion that exists between the parent and child, is the total want of correspondence between the circulation of the two. By applying the stethoscope to the abdomen of a pregnant female, the beating of the fœtal heart is observed to be twice as frequent as that of the mother. (See p. 503 of this volume.) Again, examples have occurred in which the fœtus has been extruded with the placenta and membranes entire.[4] In a case of the kind that occurred to Wrisberg, the circulation continued for nine minutes; in one described by Osiander,[5] for fifteen minutes; in some, by Professor Chapman, from ten to twenty minutes; and in one, by Professor Channing, of Boston, and Dr. Selby, of Tennessee, where

[1] Mussey, in Amer. Journ. of the Med. Sciences for November, 1829.

[2] Granville, Graphic Illustrations of Abortion, &c., p. xx., Lond., 1834.

[3] Précis Élémentaire, ii. 552.

[4] Granville, op. cit., part x., London, 1834.

[5] Annalen, B. i. S. 27.

a bath of tepid water was used to resuscitate the fœtus, for an hour,[1] Marson[2] and Flajani relate cases in which life continued for the same time: Dr. Nehr,[3] of Rehau, in Bavaria, has recorded one in which the circulation of the child was unequivocal for seven hours after the sudden and decided death of the mother; and others are referred to by D'Outrepont in his comments on this.[4] In cases of a similar kind, where the child could scarcely breathe and was in danger of perishing, the life of the placenta was maintained by keeping it in water of a temperature nearly equal to that of the body, and the child was saved. All these facts prove demonstratively, that the fœtus carries on a circulation independently of that of the mother; and whatever passes between the fœtal and maternal vessels is probably exhaled from the one and absorbed by the other, as the case may be. The fluid sent to the fœtus is supposed by some—indeed by most—physiologists to be the maternal blood, modified or unmodified. Schreger,[5] however, and others maintain, that the communication of any nutritious fluid from the mother to the fœtus, and conversely, takes place by means of lymphatics, and not by bloodvessels; and that the maternal vessels exhale into the spongy tissue of the placenta the serous part of the blood, which is taken up by the lymphatics of the fœtal portion, and conveyed into the thoracic duct. The views of Mr. Goodsir in regard to the absorbing tufts of fœtal vessels have been given already, when describing the placenta.

It has been remarked before, that Lobstein[6] and Meckel[7] suppose, that the gelatinous substance of the cord is one of the materials of fœtal nutrition; which opinion they found on the circumstance of the albuminous nature of the substance, and the great size it gives to the cord at the early periods of fœtal life, as well as on the great developement of the absorbent vessels of the fœtus, which proceed from the umbilicus to the anterior mediastinum;—and that others include, also, the fluids of the umbilical and allantoid vesicles. All these speculations regarding the various sources of nutritive matter, are sufficient evidence of the uncertainty that prevails on this interesting topic. It is manifest, however, that we cannot regard those substances to be nutritive to the fœtus which are secreted by itself. It is impossible, that any developement can occur without the reception of materials from without. We have seen, that when the ovum passes from the ovarium to the uterus, it contains, within it, a molecule, and fluids destined doubtless for its nutrition, and which afford the necessary pabulum for the increase, that occurs between the period of impregnation and that at which an adhesion is formed between the ovum and the inner surface of the uterus. The mother, having provided the nutritive material in the ovum, she must continue to do so in the uterus; and as soon as the vascular communication is formed between

[1] Horner's Special and General Anatomy, 5th edit., ii. 277, Philad., 1839.
[2] Lond. Med. Gazette, August, 1833.
[3] Neue Zeitschrift für Geburtskunde, von Busch, D'Outrepont und Ritgen, Band. iv. Heft 1, S. 58, Berlin, 1836.
[4] Ibid., S. 60.
[5] De Functione Placentæ Uterinæ, Erlang., 1795.
[6] Essai sur la Nutrition du Fœtus, Strasbourg, 1812.
[7] Handbuch, u. s. w., Jourdan and Breschet's translation, iii. 785, Paris, 1825.

the exterior of the ovum and the interior of the uterus, nutritive elements are doubtless received by the embryo;—for otherwise it would perish from inanition. What, then, it has been asked, can be the nature of these elements? Do they consist of maternal blood, laid hold of by the fœtus at this early period, when no circulatory system is apparent; or are bloodvessels distributed to the membranes of the ovum, to enable them to continue the secretion of a nutritive matter, similar to that which they took with them from the ovarium, and which must necessarily have had a maternal origin? Neither supposition is probable; yet there is great reason for the belief, that the liquor amnii is secreted from the interior of the uterus, and passes through the membranes of the ovum by imbibition. If we admit it to be, indeed, in any manner inservient to nutrition, its production must be extraneous to the body it has to nourish. These observations apply equally to the jelly of the umbilical cord, which probably passes through the membranous envelopes, and may consequently be regarded as a nutritive material derived from the parent. Both, it is true, might be secreted by the fœtus from fluids furnished by the mother, and be placed in depot, as the fat is in after existence.

Philosophical Anatomy, then, instructs us, that the placenta and umbilical cord are not indispensable to fœtal nutrition; and compels us to infer with Meckel[1]—one of the most eminent of modern anatomists and physiologists—that the human placenta may have no direct agency in embryotrophy. M. Cazeaux,[2] indeed, maintains, that "the placental vascular apparatus does not contribute to the nutrition of the fœtus." We are, therefore, necessarily driven to the conclusion, before stated,—that, in order for a fœtus to be developed in utero, it is but necessary, that there shall be an absorbing surface, surrounded by a nutritive substance, that will admit of being absorbed. Now, the cutaneous envelope of the fœtus—monstrous or natural—is such a surface, and the liquor amnii such a fluid; and after the placenta is formed, it may lend its aid. Its great function probably is to admit of the fœtal blood being *shown* to that circulating in the maternal vessels, so that some change may be effected in the former, which may better adapt it for serving as the pabulum, whence the secretions, from which the fœtal organs have to be elaborated, may be formed. According to Dr. Reid,[3] the blood of the mother, contained in the placental sac already described, and the blood of the fœtus contained in the umbilical vessels, can readily act and react on each other through the spongy and cellular walls of the placental vessels and the thin sac ensheathing them, in the same manner as the blood in the bronchial vessels of aquatic animals is acted upon by the water in which they float. If we admit this, however, it is obvious, that the nutritive fluid, when received into the system, will have to be converted into blood by the action of the fœtus, in a manner bearing some analogy to what occurs in the adult, or in the simplest of living beings in which the nutritive fluid is absorbed at the surface of the body. Of the mode in which such conversion is effected we are in the darkness

[1] Op. citat.
[2] Op. cit.; or translation by Dr. R. P. Thomas, p. 216, Philadelphia, 1850.
[3] Edinb. Med. and Surg. Journ., Jan., 1841, p. 8.

that envelopes all the mysterious processes which are esteemed organic and vital; but that the fœtus is capable of effecting it we have irrefragable proof in the oviparous animal, where there can be no communication, after the egg is laid, between the embryo and the parent. Yet we find it forming its own blood from the yolk that surrounds it, and undergoing its full and regular developement from impulses seated in itself alone.

Of those physiologists, who consider that the mother sends her blood to the placenta, to be taken up by the fœtal vessels, all do not conceive that it is in a state adapted for the nutrition of the new being: some are of opinion, that the placenta, or the liver, or both, modify it, but in a manner which they do not attempt to explain. In favour of an action being exerted by the placenta, they state that it is clearly the organ which absorbs the fluid, and that every organ of absorption is necessarily one of elaboration;—a principle which we have elsewhere proved to be unfounded; and, moreover, that the blood conveyed to the fœtus by the umbilical vein differs essentially in colour from that conveyed to it by the umbilical arteries, which, we shall see, is not the fact; and, if it were, could be accounted for more satisfactorily. In support of the view, that a second change is effected in the liver, they affirm, that a great part of the fœtal blood ramifies in the substance of that organ before it reaches the heart; a part only going by the ductus venosus; and that the great size of the liver, during fœtal life, when its function of secreting bile can be but sparingly exerted, is in favour of this notion.[1] The opinion, that some change is effected upon the blood in the liver, is certainly much more philosophical and probable than the belief of Haller, that the object of its passage through that organ is to deaden the force with which the mother projects the fluid into the fœtal vessels. We have seen, that it is extremely doubtful, whether she transmits any; and that if she does, the communication is very indirect. M. Geoffroy Saint-Hilaire[2] appears to think, that the blood of the mother, which he conceives to be sent through the placenta to the fœtus, is unfitted for fœtal life, before it has undergone certain modifications. That, according to him, which leaves the placenta, proceeds in part to the liver, and the remainder to the heart. In the liver it forms the material of the biliary secretion, or at least of a fluid, which, when discharged into the intestines, irritates them, and provokes a copious secretion from the mucous or lining membrane. This mucus, according to M. Saint Hilaire, is always met with in the stomach and intestines of the fœtus; and the presence of meconium, and of other excrementitious matters in the intestines, shows, that digestion must have taken place. This digestion he considers to be effected upon the mucus, secreted in the manner just mentioned; and, in support of its being inservient to sanguification, he affirms, that its quantity is too great for the simple purpose of lubricating the parts; that mucus is the first stage of all organic compounds; that it predominates in all young beings; is the foundation of every organ; is more capable of assimilation than any other substance, &c. But independently of the whole of

[1] Velpeau, Traité de l'Art des Accouchemens; or Meigs's translation, 2d edit., p. 224, Philad., 1838.

[2] Philosophie Anatomique, Paris, 1818–22.

this view being entirely hypothetical, it cannot be esteemed probable, that the fœtus is nourished by one of its own secretions. All secretions must be formed from blood. Blood must, therefore, pre-exist in the fœtal vessels, and the process, indicated by M. Saint-Hilaire, be unnecessary. The same objections equally apply to the views of Drs. Lee and Robinson referred to previously (p. 569).

M. Denis made a comparative analysis of the blood of the mother and of the fœtus. He found the latter richer in solid constituents and in blood-corpuscles. The two following analyses were by him—the one of the venous blood of the mother; the other of the placental blood as it flowed from an artery of the cord. The latter was of a brown red colour, smelt of the liquor amnii, and became of a brighter hue on exposure to the air.

	Venous blood of mother.	Blood of umbilical artery.
Water	781·0	701·5
Solid residue	219·0	298·5
Fibrin	2·4	2 2
Albumen	50·0	50·0
Blood-corpuscles	139·9	222·0
Peroxide of iron	0·8	2·0
Phosphuretted fat	9·2	7·5
Osmazome and cruorin	4·2	2·7
Salts	12.5	12·1[1]

Allusion has already been made to the opinions of Schreger on fœtal nutrition. These were developed in a letter, written by him, in 1799, to Sömmering.[2] He considers that all communication of nutritious matter between the mother and fœtus takes place through lymphatics which he has described as existing in considerable numbers in the placenta and umbilical cord. The red blood flowing in the maternal vessels is too highly charged with carbon, and with other heterogeneous substances, he thinks, to serve for the nutrition of the fœtus. Its serous part, which is purer and more oxygenized, is therefore alone exhaled. The uterine arteries pour this serum into the spongy texture of the placenta, whence it is taken up by the lymphatics of the fœtal portion. These convey it along the umbilical cord to the thoracic duct, whence it passes into the left subclavian, vena cava superior, right auricle and ventricle, ductus arteriosus, and aorta; and, by the umbilical arteries, is returned to the placenta. In this course, it is mixed with the blood, and becomes itself converted into that fluid. When it attains the placenta, the blood is not poured into the cells of that organ to be transported to the mother, but passes into the umbilical vein, the radicles of which are continuous with the final ramifications of the umbilical arteries. Lateral pores, however, exist in the latter, which suffer fluids to escape, that cannot be elaborated by the fœtus, or that require again to be submitted to the maternal organs, before they are fitted for its support. These fluids, according to Schreger, are not absorbed by the veins of the uterus, but by the lymphatics of that viscus, which are so apparent in the pregnant state, and have been

[1] Simon, Animal Chemistry, by Day, Sydenham Society's edition, i. 238, London, 1845.
[2] Epistol. ad S. Th. Sömmering, De Functione Placentæ Uterinæ, Erlang., 1799. See, also, Richerand, op. cit., 13ème edit., § ccvi.

injected by Cruikshank, Meckel, &c. In his view, therefore, the conversion of the serous fluid into blood is chiefly effected in the lymphatic system; and it has been a favourite hypothesis with many physiologists, that organs, regarding whose functions we are so profoundly ignorant, and whose developement is so much greater during intra-uterine than extra-uterine existence,—as the thymus, and thyroid glands, and the supra-renal capsules,—are, in some way, connected with the lymphosis or hæmatosis of the fœtus. We have already referred to the conjectures, that these organs are diverticula for the blood of those parts the functions of which are not exerted until an after period of existence. M. Broussais[1] makes the thyroid a diverticulum to the larynx; the thymus to the lungs, and the supra-renal capsules to the kidneys. Notwithstanding these ingenious speculations, our darkness, with regard to the true functions of these singular organs, is considerable.

To conclude.—The most plausible opinion we can form on this intricate subject is, that the mother secretes the substances, which are placed in contact with the fœtus in a condition best adapted for its nutrition; that in this state they are received into the system, by absorption, as the chyle or the lymph is received in the adult,—undergoing modifications, in their passage through the fœtal placenta, as well as in every part of the system where the elements of the blood must escape for the formation of the various tissues.

With regard to the precise nutritive functions executed in the fœtal state,—and as concerns

1. *Digestion*,—it is obvious, that this cannot take place to any extent, otherwise excrementitious matter would have to be thrown out, which, by entering the liquor amnii, would be fatal to its important functions, and probably to the very existence of the fœtus. Yet that some digestion is effected is manifest from the presence of meconium in the intestines, which is probably, in part, the excrementitious matter arising from the digestion of the mucous secretions of the alimentary canal.

2. *Respiration*, as accomplished by lungs, does not exist; and we have already seen, that the idea of the fœtus possessing the kind of respiration of the aquatic animal is inadmissible. An analogous function to the respiration of the adult, however, exists as respects the changes effected upon the blood. It is probable, that blood is sent to the placenta to be there aerated, as it is in the lungs in extra-uterine life. Such was the opinion of Sir Everard Home, of Girtanner, Stein,[2] and we may say it is that of many of the most enlightened physiologists of the day. The chief arguments brought forward in support of it are,—the absolute necessity for aeration to every living being, animal or vegetable; the no less necessity to the life of the fœtus of a free circulation of blood along the umbilical cord to and from the placenta; and the analogy of birds, in which the umbilical vessels are inservient to respiration by receiving the external air through the pores of the

[1] Commentaires des Propositions de Pathologie, &c., Paris, 1829, or Drs. Hays's and Griffith's translation, p. 214, Philad., 1832.

[2] Meckel's Handbuch, u. s. w., Jourdan's and Breschet's French translation, iii. 793, Paris, 1825.

shell. so that if the shell be greased, respiration is prevented, and the chick dies.[1]

The sensible evidences of these changes being accomplished by the placenta are not like those we possess regarding the aeration of the blood in its passage through the lungs of the adult, where the venous differs so essentially from the arterial blood. It is indeed asserted, in works of anatomy, that "the effete blood of the umbilical arteries becomes regenerated in the placenta, assumes a brighter hue, and is returned to the fœtus by the umbilical vein:" but this is not in accordance with experiment and observation. Bichat[2] made numerous dissections of young pigs whilst yet in utero, and uniformly found the blood of the arteries and veins presenting the same appearance, and resembling the venous blood of the mother. Not the slightest difference was observed between the blood of the aorta and that of the vena cava, or between that of the carotid artery and of the jugular vein. He made the same observations in three experiments of a similar kind on fœtuses of the dog. He, also, frequently examined human fœtuses that had died in utero, and always found the same uniformity between arterial and venous blood: hence he concludes, that there is no difference between them in the fœtus, at least in appearance. Similar experiments by Autenrieth[3] furnished like results. Dr. Granville, too, affirms, that he has never been able to detect the least difference between the arterio-umbilical and venous-umbilical blood in the many cases he has examined,[4] and it is important to bear this fact in mind, inasmuch as the absence of such difference may be received as one of the evidences that a fœtus has not respired. The apparent identity, however, between the blood passing to the placenta by the umbilical arteries and that returning by the vein cannot be real. The slightest reflection will show, that they must differ; and such is the opinion, from observation, of Messrs. Bostock,[5] Jeffrey, and others.[6] It is from the blood, carried by the umbilical vein and distributed over the body, that all the organs of the fœtus have to derive the materials of their nutrition and developement; and being deprived of these materials, the fluid must necessarily be different in the umbilical arteries from what it is in the umbilical vein. The researches of more modern chemistry have not been directed to the fœtal blood, but M. Fourcroy[7] analyzed it, and found it differ materially from the blood of the child that had respired. He asserts, that its colouring matter is darker, and seems to be more abundant; that it is destitute of fibrin and phosphoric salts, and is incapable of becoming florid by exposure to the influence of atmospheric air. It has been found, too, that the corpuscles of fœtal blood do not resemble those of the blood of the mother. The fact, however, of the

[1] Varnishes of organic animal matters, as albumen, gelatin, &c., have no effect in preventing the transmission of air. See Towne, Guy's Hospital Reports, Oct., 1839, p. 385.

[2] Anatomie Générale, ii. 344, Paris, 1818; and Recherches Physiologiques sur la Vie et la Mort, p. 190, Paris, 1806.

[3] Dissertatio Sistens Experimenta circa Calorem Fœtûs et Sanguinem ipsius Instituta, Tubing., 1799.

[4] Graphic illustrations, &c., p. 20.

[5] Op. citat.

[6] Chapman, Philadelphia Journal of the Med. and Phys. Sciences, i. 10.

[7] Annales de Chimie, vii. 165.

similarity in appearance between the arterial and venous blood of the fœtus is no evidence that respiration is not one of the fœtal functions, inasmuch as the same thing is observed in fishes. Under the head of Circulation it was remarked, that the coloration of the blood is perhaps of no farther importance than as indicating, that the vital change of aeration has taken place in the lungs. In this case, we have the vital change effected without any such coloration. Yet how, it may be asked, is the modification in the blood produced where no placenta and no umbilical cord exist; as well as in the cases before referred to in which the fœtus continues alive for hours after the death of the mother? And can we suppose that in such cases aeration is effected by the liquor amnii containing an unusual quantity of oxygen, as has been presumed by some physiologists? We have before remarked, that Professor J. Müller was unable to detect oxygen in the liquor amnii, and found that when fish were placed in it, they died as soon as in oil.[1]. These are embarrassing questions, more easily propounded than answered. By some, it has been presumed, that the liver, even in the adult, performs a function supplementary to that of the lungs; and the great size of the organ, in the fœtus, has been conceived to favour the idea, that it may separate carbon and other matters freely from the system, and in this way be depuratory; but the grounds for this presumption are not, we think, impregnable.

3. It is in the *fœtal circulation*, that we observe the most striking peculiarities of intra-uterine existence. Of its condition at the very earliest periods, mention has been made already (page 535). The primitive circulation is connected with the existence of the umbilical vesicle; and, like it, is only of short duration. Its purpose is to convey materials of nutrition from the vesicle to the fœtus by the omphalo-mesenteric vessels. In birds the vesicle remains until the full developement of the new being,—the whole of its nutriment during incubation being furnished by the yolk.

A different circulation is established when the communication between the intestine and the umbilical vesicle ceases. The omphalo-mesenteric vessels,—reduced towards the end of the first month to a single artery and vein,—become atrophied, and disappear with the vesicle. The intra-fœtal portion of the omphalo-mesenteric vein alone persists, and continuing to receive the venous blood of the intestines by the mesenteric vein, it forms, at a later period, the trunk of the vena porta. Before this time the allantoid vesicle (Figs. 476, 477) has been developed; and a new circulation becomes established through it. The formation of the allantoid and the arrangement of its vessels have been described already.[2] This arrangement is well seen in the following figures from Coste, which exhibit the circulation as it exists at the end of the first month, when the circulation by means of the umbilical vesicle is disappearing, and that by the allantoid vesicle is becoming established. The vessels of the allantoid are at first four in number; but when the vesicle has fulfilled its function, one of the veins becomes atrophied, so that two arteries and one vein remain. These persist until birth, and form the vessels of the umbilical cord (Fig. 504).

[1] Op. cit., i. 305.

[2] Page 562.

Fig. 508.

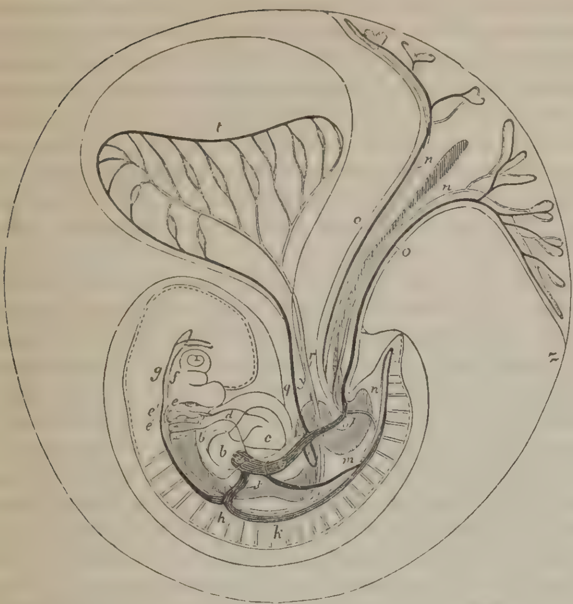


Fig. 509.

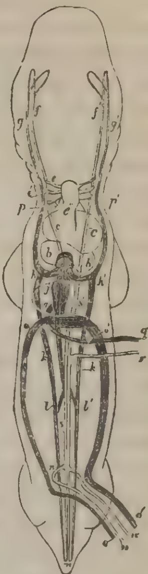


Fig. 508.—Diagram of the Circulation in the Human Embryo and its Appendages, as seen in profile from the right side, at the commencement of the formation of the Placenta.

Fig. 509.—The same, as seen from the front.

a. Venous sinus, receiving all the systematic veins; *b*, right auricle; *b′*, left auricle; *c*, right ventricle; *c′*, left ventricle; *d*, bulbus aorticus, subdividing into *e*, *e′*, *e″*, branchial arches; *f*, *f′*, arterial trunks formed by their confluence; *g*, *g′*, vena azygos superior; *h*, *h′*, confluence of the superior and inferior azygos; *j*, vena cava inferior; *k*, *k′*, vena azygos inferior; *m*, descending aorta; *n*, *n*, umbilical arteries proceeding from it; *o′*, *o*, umbilical veins; *q*, omphalo-mesenteric vein; *r*, omphalo-mesenteric artery, distributed on the walls of the vitelline vesicle *t*; *v*, ductus venosus; *y*, vitelline duct; *z*, chorion.

The mode in which the circulation is effected during the last months of fœtal existence is as follows. From the sketch already given of the circulatory organs of the mature fœtus, it will be recollected,—1st. That the two auricles of the heart communicate by an aperture in the septum, called *foramen ovale*, which has a valve opening towards the left ventricle. 2dly. That near the orifice of the vena cava inferior is the *valve of Eustachius*, so situate as to direct the blood of the cava into the foramen ovale. 3dly. That the pulmonary artery has a vessel passing from it into the aorta,—the *ductus arteriosus*. 4thly. That two arteries, called *umbilical*, proceed from the internal iliacs to the umbilicus and placenta; and lastly, that the *umbilical vein* from the placenta pours part of its blood into the vena porta; and part passes by the *ductus venosus*,—a fœtal vessel,—into the inferior cava. The course of the circulation, then, is as follows. The blood of the umbilical vein,—the radicles of which communicate with those of the umbilical arteries in the placenta,—proceeds along the vein to the umbilicus, and thence to the liver. A part of this traverses the ductus venosus, enters the vena cava inferior, and becomes mixed with the blood from the lower parts of the fœtus; the remainder passes into the vena portæ, is distributed through the

liver, and, by means of the hepatic veins, is poured into the vena cava. In this manner it retains the right auricle. Owing to the arrangement of the valve of Eustachius, the blood passes immediately through the foramen ovale into the left auricle,—without being mixed with that proceeding from the upper parts of the body into the right auricle through the vena cava superior. The left auricle is consequently as much developed as the right, which it would scarcely be did it receive only the blood from the lungs. Were it not as large, it is obvious, that it would be insufficient to carry on the circulation when the whole of the blood passes through the lungs, and is poured into it, after respiration is established.

Such are the opinions of Wolff and Sabatier[1] regarding the use of the Eustachian valve. According to this view, if the valve did not exist, the aerated blood, conveyed to the heart by the ductus venosus, instead of being directed into the left auricle through the foramen ovale, would pass into the right auricle, and thence, in part, at least, into the right ventricle; from which it would be transmitted through the pulmonary artery and ductus arteriosus into the descending aorta; so that no part of the body above the opening of the duct into the aorta could receive aerated blood, whilst much of that which passes along the aorta would be returned to the placenta by the umbilical arteries. But as the blood is directed into the left auricle by the Eustachian valve, it passes thence into the left ventricle, and by it is forced into the aorta, which distributes it to every part of the system, and thus conveys the regenerated fluid to every organ. Dr. Wistar[2] suggested, that, without this arrangement of the Eustachian valve, the coronary arteries, distributed to the heart, would be unfit for supporting the life of that organ, inasmuch as they would be deprived of a regular supply of revivified blood. From the left auricle, the blood passes into the left ventricle, and from the left ventricle into the ascending aorta, and to the upper parts of the body, from which it is brought back, by the vena cava superior, into the right auricle; thence it is transmitted into the right ventricle, and, by the contraction of the ventricle, into the pulmonary artery. By this vessel the greater part is sent through the ductus arteriosus into the descending aorta, and a small part to the lungs. Dr. Peaslee,[3] however, thinks that owing to the small size of the duct it can serve no other purpose than that of a waste-pipe to carry off the blood, what they cannot receive. But little blood, however, goes to the lungs during intra-uterine existence. From the lungs, the blood is returned into the left auricle by the pulmonary veins. Through the descending aorta, the blood, conveyed in part by the ductus arteriosus, and in part by the contraction of the left ventricle, is distributed, partly to the lower extremities, from which it is returned by corresponding veins into the vena cava inferior, and partly by the umbilical arteries to the placenta.

This view of the circulation supposes—what is disputed—that the blood of the vena cava superior and that of the vena cava inferior do not

[1] Traité Complet d'Anatomie, ii. 224, and iii. 387; and Mémoir. de l'Académ. des Sciences pour 1744.

[2] System of Anatomy, 3d edit., edited by Dr. Horner, ii. 76, Philad., 1823.

[3] American Medical Monthly, May, 1854.

undergo admixture in the right auricle; whence it would follow that some parts of the body receive a purer blood than others,—the upper parts, as the head and neck, receiving that which flows immediately from the placenta, whilst the lower do not obtain it until it has circulated through the upper. Under any view it is manifest, that not the whole of the blood is distributed to the organ of aeration, as in the adult, but a part only, as in the batrachia.

Bichat and Magendie[1] contest the explanation of Wolff and Sabatier regarding the use of the valve of Eustachius and the non-admixture of the blood of the two cavæ in the right auricle. In their opinion, the two bloods do commingle; but owing to the existence of the foramen ovale, and the arrangement of the valve of Eustachius the left auricle is filled simultaneously with the right; and, consequently, the same kind of blood must be distributed to both the upper and lower portions of the body. The uses of the foramen ovale and ductus arteriosus are explained as follows. As the left auricle receives but little blood from the lungs, it could furnish only a small quantity to the left ventricle, did it not receive blood through the foramen ovale; and, again, as the lung is exerting no function during the state of fœtal life, the blood is sent along the pulmonary artery and ductus arteriosus into the aorta, so that the contraction of both ventricles is employed in propelling the blood along the aorta to the lower parts of the body and the placenta. Without this union of forces, it is conceived, the blood could not be urged as far as the placenta.

Experiments by Dr. John Reid[2] favour the views of Wolff and Sabatier. He took a fœtus of about seven months, and threw simultaneously a red-coloured injection up the vena cava inferior, and a yellow-coloured one down the vena cava superior. On tracing the red injection upwards, it was found to have passed through the foramen ovale, and to have filled the left side of the heart, without any intermixture with the yellow, except very slightly at the posterior part of the right auricle. Not a drop of the yellow appeared to have accompanied the red to the left heart. From the left heart it ascended the aorta, and filled all the large vessels going to the head and upper extremities. The injection, in all these vessels, had not the slightest tinge of yellow. On tracing the yellow injection downwards, he found it filling the right auricle and ventricle, whence it proceeded along the pulmonary artery, and filled the ductus arteriosus, and the branches proceeding to the lungs. On entering the aorta, it passed down that vessel, filling it completely without any admixture of red, so that all the branches of the thoracic and abdominal aorta were filled with the yellow. From this and other experiments of a similar kind Dr. Reid infers, that the blood, returning from the placenta, passes principally to the head and upper extremities; and that the lower part of the body is chiefly supplied by blood returning by the vena cava superior; or, in other words, by blood that has already gone the circuit of the body. The observations, however, of Dr. T. Williams[3] have convinced him, notwithstanding the opposing experiments of Dr. Reid, that the Eustachian valve

[1] Précis Élémentaire de Physiologie, 2de édit., ii. 550, Paris, 1825.
[2] Edinb. Med. and Surg. Journ., xliii. 308.
[3] London Med. Gaz., March 31, 1843.

is mechanically inefficient in preserving the individuality of the two currents from the vena cava as they traverse the right auricle; and he affirms, that at the period of its diastole, when the auricle has attained a moderate distension, it may be readily demonstrated, that the two streams must intermingle freely. Hence, it is not true—he infers—that the difference of quality, between the blood distributed to the two portions of the body of the fœtus is as great as is generally taught by anatomists.

After all, the great difference between the adult and the fœtal circulation is,—that in the former, a part of the blood only proceeds to the organ of sanguification; that the aerated blood is poured into the right auricle instead of the left; that, instead of proceeding through the lungs, a part of the blood gets at once to the left side of the heart, whence it is sent to the head and upper extremities, and the remainder goes directly from the pulmonary artery into the aorta; and that a part of the aortic blood proceeds to the lower extremities, and the remainder goes to the placenta, from which it is returned into the inferior cava.

4. With regard to the *nutrition*, (properly so called,) of the fœtus, it is doubtless effected in the same manner as in the adult; and our ignorance of the precise nature of the mysterious process is equally great. During the whole of fœtal existence it is energetically exerted; and especially during the earlier periods. Sömmering has asserted, that the growth of the fœtus fluctuates; that it is greatest in the first month; in the second, less; in the third, greater; less, again, in the fourth; and again greater until the sixth, when it diminishes until birth.

There is a singular circumstance connected with the nutrition of the fœtus, that cannot be passed over without a slight notice, although, in its details, it belongs more properly to pathological anatomy. Owing to inappreciable causes, the different parts of the fœtus, or some particular part, may be preternaturally developed, or be defective, so as to give rise to *anomalies* of conformation, or what have been termed *monstrosities,—vitia primæ conformationis.* Three kinds of monsters may be considered to exist. The *first* comprises such as are born with an excess of parts, as with two heads to one trunk, two trunks to one head; with four arms and four legs; twins with a band uniting them, as in the case of the Siamese twins, &c. The *second* includes those in which parts are defective, as acephali, anencephali, &c.; and the *third*, those in which there is perversion of the formative process, so as to produce various modifications in the direction and situation of organs,—as where the heart is on the right side, the liver on the left, &c.; in other words where there is *transposition of the viscera.* In these cases there is respectively—to use the language of the German pathologists—*superabundant*, *defective*, and *perverted* action of the force of formation—the Bildungstrieb—to which we have more than once alluded.

The hypotheses, that have been advanced to account for these formations, as well as for those in which the parts are irregularly developed, may be reduced to three. *First.* The influence of the imagination of the mother on the fœtus in utero. *Secondly.* Accidental changes experienced by the fœtus at some period of uterine existence; and

Thirdly. Some original defect or fusion of the germs. The *first* of these causes has been a subject of keen controversy amongst physiologists at all periods. We have seen, that the mother transmits to the fœtus materials for its nutrition; and that, to a certain extent, nutrition is influenced by the character of the materials transmitted; so that if these be not of good quality, or in due quantity, the fœtus may be imperfectly nourished, and even perish. Any violent mental emotion may thus destroy the child, by modifying the quantity or quality of the nutritive matter sent to it. Small-pox, measles, and other contagious diseases can be unquestionably communicated to the fœtus in utero; so that its life is indirectly but largely dependent upon the condition of the mother; and many striking examples of the influence of the mother on the constitution of her unborn babe are given by Dr. Combe.[1] But the maternal influence has been conceived to extend much beyond this; and it has been affirmed, that her excited imagination may occasion an alteration in the form of particular parts of the fœtus, so as to give rise to *nævi*, and to all kinds of *mother's marks*, as they have been termed. These may consist of spots resembling raspberries, grapes, &c.; or there may be defective formation of particular parts,—and some of the cases that have been brought forward in favour of their having been induced by impressions, made upon the mother during pregnancy, are sufficiently striking. There are numerous difficulties, however, in the way of accepting the cause assigned. If a child has been born with nævi of any kind, the recollection of the mother is racked to discover whether some event did not befall her during gestation to which the appearance may be referred, and it is not often difficult to discover plausible means of explanation. Cases have occurred in which the mother, when a few months advanced in pregnancy, had been shocked by the sight of a person who had lost a hand, and the child has been born with the same defect. A young female, a few months gone with child, visited a brother in one of the hospitals of London, who was wounded in the side. His condition affected her extremely. Her child was born with a deep pit in the same part that was wounded in the brother. These are samples of the thousands of cases that have been recorded. Similar instances have been related of the inferior animals. In the extracts from the minute book of the Linnean Society of London, an account is given, by Mr. George Milne, F. L. S., of the effect of the imagination of a cat on her young. One afternoon, whilst Mr. Milne and his family were at tea, a young cat which had arrived at the middle of gestation, was lying on the hearth. A servant, by accident, trod very heavily on her tail; she screamed violently, and from the noise emitted, it was evident, that a considerable degree of terror was mingled with the feeling from the injury. From so common a circumstance no extraordinary result was expected; but, at the full time, she dropped five kittens, only one of which was perfect: the other four had the tail remarkably distorted; and all in the same manner.[2]

[1] Treatise on the Physiological and Moral Management of Infancy, Amer. edit., p. 67, Phila., 1840.

[2] Fleming's Philosophy of Zoology, vol. i. p. 406, Edinb., 1822.

Are we to consider these and similar cases of malformation or monstrosity to be dependent upon the influence of the maternal imagination on the fœtus in utero? Or are we to regard them as coincidences, the cause being inappreciable, but such as gives occasion to vicious organization, where no coincidence with excited imagination can be discovered? Under the head of Generation we have shown the difficulty in believing, that the mother's fancy can have any effect—as to sex or likeness—during a fecundating copulation. Let us, then, inquire what we have to admit in a case where a female is, we will suppose, four months advanced in pregnancy, when she is shocked at the appearance of one who has lost his arm, and the child is born with a like defect. It has been seen, that the communication between the mother and fœtus is of the most indirect kind; that the circulation of the fœtus is totally distinct from that of the mother; and that she can only influence the fœtus through the nutritive material she furnishes, —whatever be its character,—and, consequently, that such influence must be exerted on the whole of the fœtus, and not on any particular part. Yet, in the case we have assumed, the arm must have been already formed, and the influence of the mother's fancy have been exclusively exerted upon its absorbents, so as to cause them to take up that which had been deposited!

This assumed case is not environed with more difficulty than any of the kind. It is a fair specimen of the whole. Yet how impracticable to believe, that the effect can be connected with the assigned cause, and how much more easy to presume that the coincidence has been accidental. Cases of hare-lip are perpetually occurring, yet we never have the maternal imagination invoked as the cause; because it is by no means easy to discover a similitude between the affection and common extraneous objects. Moreover, in animals of all kinds—even in the most inferior, as well as in plants—monstrous formations are incessantly occurring where maternal imagination is out of the question. As a cause of monstrosity, therefore, its influence has been generally regarded as an inadmissible hypothesis, and by many has been esteemed ridiculous; yet it manifestly receives favour with Sir Everard Home;[1] and Professors Elliotson[2] and Burdach[3] appear inclined to favour it; but on the whole we are justified in adopting the opinion of Dr. Blundell, which has been embraced by Drs. Allen Thomson[4] and Wagner,[5] that it is contrary to experience, reason, and anatomy, to believe that the strong attention of the mother's mind to a determinate object or event can cause a determinate or specific impression upon the body of her child, without any force or violence from without; and that it is equally improbable, that, when the imagination is operating, the application of the mother's hand to any part of her own body, will cause a disfiguration or specific impression on a corresponding part of the body of the child. The *third* hypothesis, with regard to defective germs, has been canvassed under the head of Generation,

[1] Philos. Transactions for 1825, and Lect. on Compar. Anat., v. 190, Lond., 1828.
[2] Translation of Blumenbach's Physiology, 4th edit., p. 497, Lond., 1828.
[3] Die Physiologie als Erfahrungswissenschaft, B. ii.
[4] Art. Generation, Cyclop. of Anat. and Physiol., P. xiii. p. 477, February, 1838.
[5] Elements of Physiology, translated by Dr. Willis, p. 227, note, Lond., 1841.

and deemed insufficient. The *second*, consequently, alone remains, and is almost universally adopted. Independently of all disturbing influences from the mother, the fœtus is known to be frequently attacked with spontaneous diseases, as dropsy, ulceration, gangrene, cutaneous eruptions, &c. Some of these affections occasionally destroy it before birth. At other times, it is born with them; and hence they are termed *connate*, or *congenital*. The following table, drawn up by Mr. Wilde[1] from the records of the Gebäranstalt, of Vienna, exhibits the malformations observed in 23,413 births.

Clubfoot,	16	cases, or	once in	1463·31
Hare lip,	20	"	"	1170·65
——— simple,	9	"	"	2601·44
——— with cleft palate,	11	"	"	2128·45
Spina bifida,	5	"	"	4682·6
Hydrocephalus,	6	"	"	3902·16
Six fingers,	3	"	"	7804·33
Imperforate anus,	2	"	"	11706·5
Hemicephalia,	1	"	"	23413
Acephalia,	1	"	"	23413
Umbilical hernia,	1	"	"	23413
Without eyes,	2	"	"	11706·5
Wanting superior part of vertex,	1	"	"	23413
Lenticular cataract,	1	"	"	23413
Wanting one upper extremity,	2	"	"	11706·5
With plurality of fingers and toes,	5	"	"	4682·6
Hydrocephalus with spina bifida, and closed anus,	1	"	"	23413
Clubfoot and closed anus,	1	"	"	23413

In a population, consequently, chiefly illegitimate, 88 deviations from the natural type occurred in 23,413 births, or about 1 in every 266 cases.

Where a part has been wanting, the nerve, or bloodvessel, or both, proceeding to it, have likewise been found wanting; so that the defect of the organ has been thus explained; without our being able, however, to account for the deficiency of such nerve or bloodvessel, which is the main point.

In some cases of monstrosity, a fusion of two germs seems to have occurred. Two vesicles have been fecundated and subsequently commingled, so that children have been produced with two heads and one trunk, or with two trunks and one head, &c. &c. This is one mode of accounting for the whole class of monsters by excess, including those commonly called *double monsters;* but it can scarcely be presumed, that the slighter cases of monstrosity by excess,—six fingered children, for example—are produced by the fusion of germs;—and, accordingly, Professor Vogel[2] ascribes them to the "*furcation*" of a single germ," and Professor Vrolik[3] is in favour of the view of excess or irregular distribution of developemental power, and prefers to regard those cases "as examples rather of singleness tending to duplicity than of duplicity tending to singleness;" and the reasons he assigns for this view, and for rejecting the hypothesis of fusion, are:—"that it is probable, that the whole class of monsters by excess owe their origin to different

[1] Austria, &c., p. 224. Dublin, 1843.
[2] The Pathological Anatomy of the Human Body, translated by Dr. Day, p. 509, Lond., 1847.
[3] Art. Teratology, Cyclopædia of Anatomy and Physiology, iv. 976, Lond., 1852.

degrees of one common fault, and, consequently, that the explanation of their origin ought to be the same for all;—that no kind of fusion can account for the production of supernumerary individual organs, the rest of the body being single; but that it is not impossible, that excess of power in the ovum, which, all admit, can alone explain the lower degrees of duplicity, may, in proportionally higher degrees, perhaps by the formation of two primitive grooves, produce the more complete double monsters, or even two such separate individuals as are sometimes found within a single amnion."

Such, too, is the view embraced by, Rokitansky,[1] and by Dr. Carpenter.[2] "There is," says the latter, "another class of objects, to which tumours come into close relation, and which must be referred, like them, to a local excess of formative activity; these are the supernumerary parts which are not unfrequently developed during fœtal life, as for example, additional fingers and toes. It seems absurd to refer these, formed, as they are, by simple outgrowth from the limbs to which they are attached, to the fusion of germs; which has been hypothetically invoked to explain more important excesses, as those of additional limbs, double bodies or double heads; and yet, from the lower to the higher form of excess, the transition is so gradual, that what is true of the former can scarcely but be true of the latter. Hence even complete double monsters must be regarded, not as having proceeded from two separate germs, which have become partially united in the course of their developement, but from a single germ, which being possessed of an unusual formative capacity has evolved itself into a structure containing more than the usual number of parts, and comparable to that which may be artificially produced by partial fusion of the bodies of many of the lower animals. We can scarcely fail to recognize, throughout this whole series of abnormal productions, the operation of a similar power. In the formation of a supernumerary part, this has been sufficient, not merely to produce the tissues, and to develope them according to a regular morphological type, but to impart to the fabric, thus generated, a separate and even independent existence; thus evolving an additional finger or thumb on each hand, a double pair of arms or legs, a double head or trunk, or even a complete body."

Yet although the view may seem to Dr. Carpenter to be "absurd," it certainly appears much more probable, that complete double monsters—the Siamese twins, for example—are evolved from two germs, than that they can arise from the increased formative action of one germ; whilst supernumerary parts—additional fingers and toes for example—may be properly referred to local excess of formative activity.

Bischoff[3] refers monstrosities with the number of parts in excess to various causes. *First*, to original formation of the germ. *Secondly*,

[1] Manual of Pathological Anatomy, Sydenham Society's edition, i. 30, London, 1854.

[2] Principles of Human Physiology, Amer. edit., by Dr. F. G. Smith, p. 340, Philad., 1855.

[3] Art. Entwickelungsgeschichte mit besonderer Berücksichtigung der Missbildungen, in Wagner's Handwörterbuch der Physiologie, 6te Lieferung, S. 914, Braunschweig, 1843.

to an uncommonly energetic developement of an originally single germ, induced probably by external causes. *Thirdly*, to an *ovum in ovo;* and *fourthly*, to arrest of developement, (as in the ossa Wormiana.)

This interesting department of pathological anatomy has become, of late years, of moment as elucidating the normal formation of the animal body, which appears to be effected—even in the production of anomalies—in accordance with a unity of organic composition, and with laws of developement but little appreciated until the present century, and still sufficiently obscure. The labours of Geoffroy and Isidore Saint-Hilaire, Serres, Sömmering, Meckel, Tiedemann, Béclard, Gurlt, Breschet, Allen Thomson, Vrolik, Rokitansky, and others, have—as Cuvier remarked of some of them—occasioned the accumulation of an infinity of facts and views, which, even if we do not admit all that their authors contend for, cannot fail to be of solid advantage to science.

5. That the fœtal *secretions* are actively formed is proved by the circumstance, that all the surfaces are lubricated nearly as they are afterwards. The follicular secretion is abundant, and at times envelopes the body with a layer of sebaceous matter—*vernix caseosa*—of considerable thickness. Vauquelin and Buniva[1] have asserted, that this is a deposit from the albumen of the liquor amnii; but it is not found except on the body of the fœtus. It is not on the placenta or umbilical cord, and is most abundant on those parts of the fœtus, where the follicles are most numerous. Fat also exists in quantity after the fifth month. The greatest question has been in regard to the presence of certain secretions that are of an excrementitious character. For example,—by some, the *urinary secretion* is supposed to be in activity from the earliest period of intra-uterine existence, and its product to be discharged into the liquor amnii. Such is the opinion of Meckel.[2] The circumstances that favour it, are,—the fact of the existence of the kidneys at a very early period; and that at the full time the bladder contains urine, which is evacuated soon after birth. On analysis, this is found to be less charged with urea and phosphoric salts than afterwards. A recent analysis exhibited it to be an albuminous fluid, free from sugar, containing some of the usual salts of the urine, abounding in a highly nitrogenized principle, probably allantoin; affording no urea, "and depositing a remarkably large amount of nucleated basement epithelium."[3]

Of the *meconium* we have already spoken (p. 568). It is manifestly an excretory substance, produced, probably, by the digestion of the fluids of the alimentary canal, mixed with bile. Some, indeed, are of opinion, that it is altogether a secretion from the liver, and intended to purify the blood sent by the mother, as to adapt it for the circulation of the fœtus. Into the value of the theory on which this notion rests, we have inquired at some length. The notion itself scarcely requires further comment.

[1] Annales de Chimie, tom. xxxiii.; and Mémoir. de la Société Médicale d'Emulation, iii. 229.

[2] Handbuch, u. s. w.; or French translation by Jourdan and Breschet, iii. 780; or the English translation by S. A. Doane, Philad., 1832.

[3] W. Moore, Dublin Quarterly Journal of Med. Science, August, 1855; or Brit. and For. Med.-Chir. Rev., Jan., 1856, p. 233.

6. The *animal temperature* of the fœtus cannot be rigorously determined. The common belief is, that it is some degrees lower than that of the mother; and it is affirmed, that the temperature of the dead fœtus is higher than that of the living. If such be the fact, it must possess means of refrigeration. M. Edwards found, in his experiments, that the temperature of new-born animals is inferior to that of the adult; which is in accordance with the general belief regarding that of the fœtus in utero. In some cases, as in those of the kitten, puppy, and rabbit, if the young be removed from the mother, and exposed to a temperature of between 50° and 70°, the temperature will sink,—as happens to the cold-blooded animal,—to nearly the same degree. He found the faculty of producing heat to be at its minimum at birth; but it progressively increased, until in about fifteen days the animal acquired the power in the same degree with the adult. This was not the case, however, with all the mammalia. It seemed to be confined to animals that are born blind; in which a state of imperfection probably exists in other functions. It was the same with birds as with mammalia: birds, hatched in a defective state, as regards their organs generally, have the power of producing heat defective; whilst others, born in a more perfect condition, have the organs of calorification more capable of exercising their due functions. In a case in which the mother, who had borne five children, was confident that her period of gestation was less than 19 weeks, but probably from the length and weight of the fœtus it was 25 weeks, the power of calorification of the latter was so low, that artificial heat was constantly needed to sustain it: under the influence of the heat of the fire, however, it evidently became weaker, whilst the genial warmth of a person in bed rendered it lively and comparatively strong.[1]

Opinions with regard to the temperature of the human infant vary. Haller[2] asserts that it has less power of producing heat than the adult, and such is the opinion of MM. Despretz, Edwards,[3] and the generality of physiologists. The latter gentleman estimated it at 94·25° of Fahrenheit. On the other hand, Dr. John Davy[4] affirms, that the temperature of young animals generally, and that of a new-born child, which he particularly examined, was higher than that of the adult. It is impossible to account for this discordance; but the general results of experiments would seem to agree with those of M. Edwards. Howsoever this may be, the fœtus certainly possesses the power of producing its own caloric; otherwise its temperature should correspond with that of the mother, which, we have elsewhere seen, is not the fact.

b. *Animal Functions.*

The *external senses* in general are manifestly not in exercise during fœtal life: of this there can be no doubt, as regards the *sense of sight*; and the same thing probably applies to *taste*, *smell* and *hearing*. With regard to *tact*, however, we have the best reason for believing, that it exists, particularly towards the latter periods of utero-gestation.

[1] Edinb. Medical and Surgical Journal, vol. xi.

[2] Element. Physiol., vi. 3.

[3] De l'Influence des Agens Physiques, Paris, 1824.

[4] Philos. Transact. for 1814, p. 602.

Either in a senso-motory or reflex manner, the cold hand, applied over the abdomen of the mother, instantly elicits the motions of the child. The brain and nervous system of the fœtus must, therefore, have undergone the developement necessary for the reception of tactile impressions made through the medium of the mother; for conveying such impression to the percipient organ, and accomplishing perception.

The existence of *internal sensations* or *wants* would be supererogatory in the fœtal state, where the functions, to which they minister after birth, are themselves wanting. It is probable, that there is no digestion except of the mucous secretions of the tube; little or no excretion of fæces or urine; and certainly there is no pulmonary respiration. It is not unlikely, however, that internal impressions, originating in the very tissue of the organs, may be communicated to, and appreciated by, the encephalon. We have strong reason for believing, that pain may be experienced by the fœtus; for if it be destroyed by any sudden influence in the later periods of pregnancy, death is generally preceded by irregular movements manifest to the mother, and frequently leading her to anticipate the result. M. Adelon asks, whether it may not be affected, under such circumstances, with convulsions, similar to those that animals experience when they die suddenly, especially from hemorrhage? It is impossible to reply positively to the question; but that the child suffers appears evident.

The most elevated of the functions of relation—the *mental* and *moral faculties*—would seem to be needless in the fœtus; and consequently can be little, if at all, exercised. MM. Bichat and Adelon,[1] considering that its existence is purely vegetative, are of opinion that they are not exerted. M. Cabanis,[2] however, suggests, that imperfect essays may, at this early period, be made by virtue of the same instinct that impels animals to exercise their organs prior to the period at which they are able to derive service from them; as in the case of the bird, which shakes its wings before they are covered with feathers. It is difficult to deny to the fœtus *all* intellectual and moral manifestations. They must, doubtless, be obscurely rudimental; still, we may conceive that some may exist, if we admit that the brain is in a state for the perception of impressions; that tact is practicable, and instinct in activity. We find, moreover,—that the power of *motion*, voluntary as well as involuntary, exists after the fifth month, and probably much earlier, could it be appreciated. During the latter months of utero-gestation, the motion appears to be almost incessant, and can be distinctly felt by placing the hand upon the abdomen. At times, indeed, it is manifest to the sight. The cause of these movements is by no means clear. It is probable, that they are instituted for the purpose of changing the position, which may have become irksome; for we have already remarked, that the fœtus readily appreciates any sudden succussion given to it through the mother, and hence that it possesses tact, and, as we can readily understand, may experience fatigue from the maintenance of an inconvenient posture, and send nervous influence to the appropriate muscles to change it. Dr. Simpson[3] main-

[1] Physiologie de l'Homme, 2de édit., iv. 420, Paris, 1829.
[2] Rapport du Physique et du Moral de l'Homme, Paris, 1802.
[3] Edinb. Monthly Journal of Science, July, 1849.

tains, that the motions are altogether excito-motory; and that the position of the fœtus in utero, or—as he expresses it—"the adaptive position of the contained to the containing body is the aggregate result of reflex movements on the part of the fœtus by which it keeps its cutaneous surface as far as possible from causes of irritation." All this proves, that the encephalic and spinal functions are exerted; but only for a few definite objects.

The function of *expression* is almost, if not entirely, null in the fœtus. There are cases on record, where children are said to have cried in utero, so as to have been heard distinctly, not only by the mother, but by those around her. Indeed, the objection, that an infant may respire before it is born, and yet not come into the world alive,—in which case there will be buoyancy and dilatation of the lungs,—has been brought forward against the docimasia pulmonum or *lung-proof* of infanticide. It is impossible for us to consider the cases of the kind that have been recorded as mere fabrications, or the phenomenon to be impossible,—except, indeed, whilst the membranes are in a state of integrity. When they have given away, and the child's mouth presents towards the os-uteri, breathing and *vagitus* may be practicable; yet very positive and unexceptionable testimony is required to establish such an occurrence.[1]

c. *Functions of Reproduction.*

These require no consideration. They are inactive during the fœtal state, except that the testicles secrete a fluid which is not sperm, and is found in the vesiculæ seminales. A milky fluid is secreted by the breasts of infants, which has been examined by Guillot and Schlossberger,[2] and found to possess the characters of the milk of the mother, separating into a serous and a creamy portion.

It would appear, as before remarked, that ovarian vesicles are already existent in intra-uterine life.

[1] Taylor, Medical Jurisprudence, 3d Amer. edit., by Dr. Edward Hartshorne, p. 390, Philad., 1853.

[2] Cited by Dr. Day in Brit. and For. Med.-Chir. Rev., July, 1855., p. 220.

BOOK IV.

CHAPTER I.

AGES.

UNDER this head we have to include the modifications that occur in the functions from birth until dissolution. The different ages may be separated as follows:—*infancy*, comprising the period from birth until the second dentition;—*childhood*, that between the second dentition and puberty;—*adolescence*, that between puberty and manhood;—*virility*, that between youth and old age;—and *old age*. The details of the phenomena in each can only be regarded as the general application;—the exceptions being frequently numerous and remarkable, especially in the later periods of existence.

1. INFANCY.

The age of infancy extends from birth to the second dentition, or until about the seventh or eighth year: M. Flourens[1] extends it to ten years. By M. Hallé, and after him by MM. Renauldin,[2] Rullier,[3] Adelon,[4] and others, this has been subdivided into three periods, which are somewhat distinct from each other, and may therefore be adopted with advantage. The one comprises the period between birth and the first dentition,—generally about seven months; a second embraces the whole period of the first dentition, or up to about two years; and the third includes the interval that separates the first from the second dentition.

a. *First Period of Infancy.*

As soon as the child is ushered into the world, it assumes an independent existence, and a series of changes occurs in its functions of the most sudden and surprising character. Respiration becomes established, after the manner in which it is to be effected during the remainder of existence; and the whole of the peculiarities of fœtal circulation cease. The first act after the child is extruded is to breathe, and at the same time to cry. What are the agencies, then, by which the first inspiration is effected, and the disagreeable impression made? This has been an interesting topic of inquiry amongst physiologists. A few of the hypotheses that have been indulged will be sufficient to exhibit the directions which the investigation has taken.

[1] De la Longévité Humaine et de la Quantité de Vie sur le Globe, 2de édit., p. 46, Paris, 1855.
[2] Art. Age, Dictionnaire des Sciences Médicales.
[3] Art. Age, Dict. de Médecine, i. 381, Paris, 1821.
[4] Physiologie de l'Homme, 2de édit., iv. 425, Paris, 1829.

Whytt,[1]—whose views were long popular, and still have supporters,—conceived, that before birth the blood of the fœtus is properly prepared by the mother; and when, after birth, it no longer receives the necessary supply, an uneasy sensation is experienced in the chest, which may be looked upon as the appetite for breathing, in the same manner as hunger and thirst are appetites for meat and drink. To satisfy this appetite, the brain excites the expansion of the chest to prevent the fatal effects, that would ensue if the lungs were not immediately aroused to action. This appetite is supposed to commence at birth, owing to the circulation being quickened by the struggles of the fœtus, and to an additional quantity of blood passing through the lungs, which excites them to action, and seems to be the immediate cause of the appetite. Haller[2] ascribes the first inspiration to the habit, which the fœtus has acquired, whilst in the uterus, of taking into the mouth a portion of the liquor amnii; and he supposes, that it still continues to open its mouth, after leaving the mother, in search of its accustomed food. The air, consequently, rushes into the lungs, and expands them; the blood is distributed through them, and a regular supply of fresh air is needed to prevent it from stagnating in its passage from the right to the left side of the heart. Dr. Wilson Philip[3] regards the muscles of inspiration as entirely under the control of the will; and he thinks, that they are thrown into action by the uneasy sensation experienced by the infant, when separated from the mother, and having no longer the necessary changes produced upon its blood by her organs. M. Adelon thinks it probable, that the series of developements occurring during gestation predisposes to the establishment of respiration. According to him, the lungs gradually increase in size during the latter months; the branches of the pulmonary vessels become enlarged, and the ductus arteriosus diminished; so that the lungs are prepared for the new function they have to execute. In addition to these alterations, he conceives that the process of accouchement predisposes to the change; that, by the contractions of the uterus, the circulation of the blood must necessarily be modified in the placenta, and, consequently, in the fœtus;—for he is a believer in the doctrine, that the fœtus receives blood from the mother by the placenta. Owing to this disturbance in the circulation, more blood is sent to the lungs; and when the child is born, it is subjected to new and probably painful impressions. "For instance," he remarks, "the external air, by its coldness and weight, must cause a disagreeable impression on the skin of the infant, as well as on the origin of all the mucous membranes; and, perhaps, the organs of the senses being, at the same time, suddenly subjected to the contact of their proper irritants, receive painful impressions from them. These different impressions being transmitted to the brain, are reflected to the different dependencies of the nervous system, and, consequently, to the nerves of the inspiratory muscles; these muscles, thus excited, enter into contraction, in the same manner as the heart is stimulated to renew its contractions during syncope; when a stimulating vapour is inspired."

[1] An Essay on the Vital and other Involuntary Motions of Animals, Sect. ix. 109, Edinb., 1751.

[2] Elem. Physiol., viii. 5, 2.

[3] Quarterly Journal of Science, &c., vol. xiv. 100.

The view taken by Dr. Bostock[1] explains the process, as far perhaps as is practicable, on mechanical principles. The first respiratory act, according to him, seems to be purely mechanical, and to result from the change of position which the child undergoes at birth. From the mode in which it rests in utero, every thing is done that position can accomplish to diminish the dimensions of the chest; and any change in this position must have the effect of liberating the lungs from a portion of the pressure which they sustain. The head cannot be raised from the breast, nor the knees removed from the abdomen, without straightening the spine; and the spine cannot be reduced to a straight line without elevating the ribs and permitting the abdominal viscera to fall; but the ribs cannot rise nor the diaphragm descend, without enlarging the chest; and, as the chest enlarges, the lungs, which are the most elastic organs of the body, expand their air-cells, hitherto collapsed by external pressure, and the external air rushes in. The same cause is considered to account for the new circulatory movement. The blood, which, in the fœtus, had passed through the foramen ovale and ductus arteriosus without visiting the lungs, is solicited from its course by the expansion of the chest, which draws the blood through the pulmonary artery as forcibly as it does air through the windpipe. The blood, thus exposed to the air in the lungs, becomes arterialized; and, from this moment, the distinction between arterial and venous blood is established. The circulation through the vessels peculiar to the fœtal condition now ceases, even without any ligature being placed upon the umbilical cord.

On the whole, the view of Whytt, with the additions suggested by Dr. Marshall Hall, affords, perhaps, the best explanation of the phenomena. It has been elsewhere shown, that the function of respiration is partly voluntary and partly involuntary; partly, in other words, under the cerebro-spinal, and partly under the reflex system of nerves. When the *besoin de respirer* or appetite for air becomes irresistible, the reflex or true spinal system acts predominantly, and the muscles concerned in the mechanical phenomena of respiration are immediately thrown into appropriate action. The act of impression in this "want" or internal sensation is probably in the new condition of the pulmonary bloodvessels, which at birth receive a sudden and large supply of blood. From them the excitor influence is conveyed to the centre of the reflex or excito-motory system.

The sudden and important changes supervening in this manner guide us to the decision of an interesting medico-legal inquiry,—whether in a case of alleged infanticide, the child has respired or not;—in other words, whether it was born alive or dead? After respiration has been established, the lungs, from being dark-coloured and dense, become of a florid red hue; are light and spongy, and float on water: on cutting into them, the escape of air from the air-cells occasions a crepitus, and a bloody fluid exudes; there is an approach to closure of the foramen ovale; the ductus arteriosus is empty, as well as the ductus venosus; and the absolute weight of the lungs may be doubled.

[1] Elementary System of Physiology, 3d edit., p. 323, Lond., 1836.

The different conditions of the organs of circulation, of the cord and skin, at different periods, beginning at the first and ending with the thirty-fifth day, have been summed up as follows by M. Devergie,[1] from the result of numerous and careful observations. They may enable us to judge approximately of the age of the young infant, in questions of a medico-legal character. On *the first day*. Cord beginning to wither. Foramen ovale, ductus arteriosus, ductus venosus, and umbilical vessels open. *Second day*. Withering of the cord complete. Foramen ovale closed in two out of eleven cases; partially closed in one out of seven. Ductus arteriosus beginning to close. Umbilical arteries obliterated to a greater or less extent. Umbilical veins and ductus venosus still open. *Third day*. Desiccation of the cord. Foramen ovale sometimes closed. Ductus arteriosus obliterated in one in eleven cases. Umbilical arteries very often obliterated. Umbilical vein and ductus venosus still open. *Fourth day*. Cord beginning to fall off. Foramen ovale closed in about one-third of the cases. Ductus arteriosus still open in the majority of cases. Umbilical arteries closed, but sometimes open near the iliacs. Umbilical vein and ductus venosus much contracted. *Fifth day*. Separation of the cord with rare exceptions. Foramen ovale closed in more than half the cases. Ductus arteriosus closed in about half the cases. Umbilical vessels closed; vein occasionally open. Separation of the cuticle advanced. *Eighth day*. Entire separation of the cord, with commencing cicatrization. Foramen ovale closed in three-fourths of the cases. Ductus arteriosus completely obliterated in half the cases. Umbilical vessels closed. *Ninth to eleventh day*. Cicatrization of the umbilicus often complete; sometimes, however, there is an oozing of mucous matter from the cord for many days, so that the cicatrix is retarded. Separation of the cuticle on the trunk, chest, and abdomen, and at the articulations. *Twentieth to twenty-sixth day*. Separation of the greater part of the cuticle. *Thirtieth to thirty-fifth day*. Separation of the entire cuticle, excepting that of the hands and feet, which is often delayed until the *fortieth day*.[2]

Respiration having been once thoroughly established, the individual enters upon the first period of infancy, which has now to engage attention. The animal functions, during this period, undergo considerable developement. The sense of tact is little evinced, but it exists, as the child appears very sensible to external cold. At first, touch is not exerted under the influence of volition; but, towards the termination of the period, it begins to be active. Taste is almost always null at first. M. Adelon[3] thinks, that it is probably exerted on the first day as regards the fluids, which the infant sucks and drinks. We have daily evidence, however, that at an early period of existence, the most nauseous substances, provided they are not irritating, are swallowed indiscriminately, and without the slightest repugnance; but, before the termination of the period under consideration, the taste becomes inconveniently acute, so that the exhibition of nauseous substances, as of medicine, is a matter of more difficulty. Smell is probably more

[1] Médecine Légale, 2de édit., i. 552, Paris, 1840.
[2] Guy, Principles of Forensic Medicine, Part i. p. 149, Lond., 1843.
[3] Physiologie de l'Homme, edit. cit., iv. 433.

backward than any of the other senses,—the developement of its organ being more tardy, the nose small, and the nasal sinuses not in existence. In the first few weeks, sight and hearing are imperfectly exerted, but, subsequently, they are in full activity. The internal sensations, being instinctive, exist; all those at least that are connected with the animal and nutritive functions. Hunger and thirst appear during the first day of existence; the desire of passing the urine and fæces is doubtless present, notwithstanding they appear to be discharged involuntarily; and the morbid sensation of pain is often experienced, especially in the intestinal canal, owing to flatus, acidity, &c. During the first part of the period, the child exhibits no mental and moral manifestations; but, in the course of a few weeks, it begins to notice surrounding objects, especially such as are brilliant; and to distinguish between the faces to which it has been accustomed and those of strangers;—awarding a smile of recognition or of satisfaction to the former, a look of gravity and doubt to the latter. Locomotion, as well as the erect attitude, is, at this time, utterly impracticable. The muscular system is not yet sufficiently developed; the spinous processes of the vertebræ are not formed, and it has not learned to keep the centre of gravity—or rather the vertical line—within the base of sustentation. The function of expression, at the early part of the period, is confined to *vagitus* or squalling, which indicates the existence of uneasiness of some kind; but, before the termination of the period, the infant unites smiles and even laughter to the opposite expressions, and attempts to utter sounds, which cannot yet be considered as any effort at conventional language. Sleep is largely indulged. Soon after birth, it is almost constant, except when the child is taking nutriment. Gradually, the waking intervals are prolonged; but, throughout, much sleep is needed, owing to the frail condition of the nervous system, which is soon exhausted by even feeble exertion, and requires intermission of action.

After birth, the child has to subsist upon a different aliment from that with which it was supplied whilst in the womb. Its digestion, therefore, undergoes modification. The nutriment is now the milk of the parent, or some analogous liquid, which is sucked in, in the manner described under Digestion. For this kind of prehension the mouth is well adapted. The tongue is large, compared with the size of the body, and the want of teeth enables the lips to be extended forward, and embrace the nipple more accurately and conveniently. The action of sucking is doubtless as instinctive as the appetite for nutriment, and equally incapable of explanation. The appetite appears to be almost incessant, partly owing to the rapidity of growth, which demands continual supplies of nutriment; and partly, perhaps, to a feeling of pleasure experienced in the act, which is generally the prelude to a recurrence of sleep, broken in upon apparently for the mere purpose of supplying the wants of the system, or the artificial desire produced by frequent indulgence. Often, we have the strongest reason for believing, that the great frequency of the calls of the appetite is occasioned by the habit, with many mothers, of putting the child constantly to the breast; inasmuch as in children that have been trained, from an early period, to receive the nutriment at fixed hours only, the desire may

not recur or be urgent until the lapse of the accustomed interval. Digestion at this age, is speedily accomplished;—the evacuations being frequent,—two or three or more in the course of the day,—of a yellow colour, something like custard, or curdy, and having by no means the offensive smell, which they subsequently possess. During the first days after birth, they are dark and adhesive, and consist of *meconium*. Young mothers are apt to be alarmed at this appearance, which is entirely healthy, and always exists to a greater or less degree. Respiration is more frequent than in the adult, nearly in the proportion of two to one; and is chiefly accomplished by the muscles that raise the ribs, on account of the great size of some of the abdominal viscera, which do not permit the diaphragm to be readily depressed. The stethoscope exhibits the respiration to be much more sonorous; so characteristic, indeed, is it, in this respect, that by way of distinction it has been called "puerile," and appears to indicate a greater degree of activity in the respiratory function. The circulation is more rapid; —the pulsations at birth being nearly twice as numerous as in the adult. Nutrition is active in the developement of organs. Calorification becomes gradually more and more energetic from the time of birth. The recrementitial secretions, as well as the excrementitial, are as regularly formed as in the adult; but the products vary somewhat. The urine, for instance, is less charged with urea, and contains benzoic acid; and the perspiration is acidulous. M. Adelon[1] asserts, that these excretions are frequently insufficient for the necessary depuration, and that nature, therefore, establishes others, which are irregular and morbid, in the shape of cutaneous efflorescences, &c. These can scarcely be regarded as depurations; unless we consider all cutaneous eruptions, connected with gastric or digestive irritation, to be such, which is more than problematical; especially as most of them are neither pustular nor vesicular, and therefore not accompanied by any sensible exudation.

b. *Second Period of Infancy, or First Dentition.*

This period embraces the whole time of dentition, and is considered to include the age between seven months and two years. In it the external senses are in great activity, and continually furnishing the intellect with the means from without for its developement. The internal sensations are likewise active. From these united causes, as well as from the improved cerebral organization, the intellect is more strengthened during this period than perhaps during any other. The senses are continually conveying information; perception is, therefore, most active,—as well as memory; but imagination and judgment are feeble and limited. The faculty of imitation is strong, so that, by hearing spoken language, and appreciating its utility, the child endeavours to produce similar sounds with its own larynx, and gradually succeeds,—the greater part of its first language consisting of imitations of sounds emitted by objects, and these sounds applied to designate the objects themselves in the manner we have seen elsewhere.[2] The affective faculties are likewise unfolded during this period; but generally

[1] Physiologie de l'Homme, 2de édit., iv. 436, Paris, 1829. [2] Page 329.

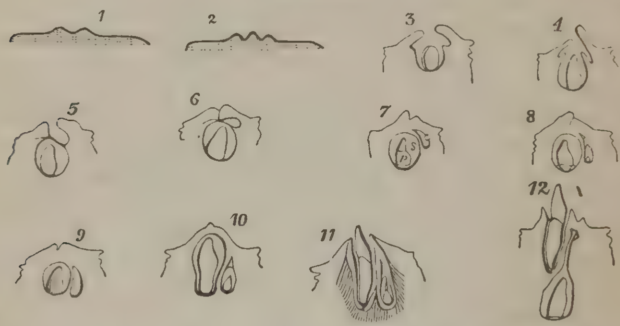
those of the selfish cast are predominant, and require careful attention for their rectification. Even at this early time of life, the effect of a well-adapted education is striking, and spares the child from numerous inconveniences, to which unlicensed indulgence in its natural passions would inevitably expose it. The general feeling is, that the infant is not yet possessed of the necessary intelligence to pursue the course indicated; but it is surprising how soon it may be made to understand the wishes of its instructor, and with what facility it may be moulded, at this tender age, in almost any manner that may be desired. During this period the child is capable of standing erect and of walking. Previously, these actions were impracticable, for the reasons already stated, as well as owing to the weight of the thoracic and abdominal viscera,—to the spine having but one curvature, the convexity of which is backwards,—to the small size of the pelvis, and its inclination forwards, so that it scarcely supports the weight of the abdominal viscera, and to the smallness of the lower limbs and the feebleness of their muscles, which are insufficient to prevent the trunk from falling forward. These imperfections are, however, gradually obviated, and the child commences to support itself on all-fours; a position assumed much more easily than the biped attitude, owing to the centre of gravity being situate low, and the base of sustentation large. In this attitude it moves about for some time, or locomotion is effected by pushing a chair before it, or by being steadied by its nurse. Gradually it passes from place to place on its feet, by laying hold of surrounding objects, and, in proportion as the bones and muscles become developed, and the obstacles to progression are removed, it succeeds in walking alone; but is some time before it is capable of running or leaping. Perhaps the average period at which the infant begins to walk is about twelve months; but we see great difference in this respect. When once fairly on its legs, the whole of the waking hours is spent in incessant activity and amusement. The functions of expression are commensurate with the intellectual developement, which, we have seen, is great in this period. Sleep, which is now more interrupted, is still imperiously and frequently demanded,—the nervous system being devoid of the strength it subsequently possesses, and therefore requiring repose.

One of the most important changes going on at this age concerns the function of digestion. This is the process of *dentition*, which usually commences about the seventh month, and continues till the end of the second year at least. Prior to the appearance of the teeth, mastication is of course impracticable; and the food best adapted for the delicate powers of the infant is that afforded by the maternal breast, or a substitute which resembles it as closely as possible. The appearance, however, of teeth would seem to indicate, that the infant is about to be adapted for more solid aliment. About the sixth week of intra-uterine life, a depression or groove, of horseshoe shape, is seen along the edge of the jaw in the mucous membrane of the gum, which is the *primitive dental groove* of Professor Goodsir;[1] and in the second month of utero-gestation, if the jaws be carefully examined, the germs of teeth are perceptible in their substance, under the form of membranous papillæ of an oval shape, attached by their deep-seated extremity to a vascular

[1] Edinb. Med. and Surg. Journal, vol. li.

and nervous pedicle, and by their superficial extremity to the gum; over which follicles are formed by the approach of processes from the sides of this primitive groove. The cavity of these follicles is at first filled with a colourless limpid fluid; but a kind of vascular and nervous papilla or pulp soon forms in it, which commences at the deep-seated portion of the follicle, proceeds towards the other extremity, and ultimately fills it,—the fluid diminishing in proportion to the increase of

Fig. 510.



Schemes of Sections of the Lower Jaw of the Fœtus at different periods, to show the stages of developement of the sac of a temporary incisor and of the succeeding permanent tooth from the mucous membrane of the jaw.

1. The dental groove is formed in the mucous membrane. 2. The groove widens, and has a papilla at the bottom: this is the papillary stage. 3, 4, and 5 represent the follicular stage; the lips of the groove enlarge, and form a sunken follicle, in which the papilla, now enlarged and beginning to acquire the form of the future tooth-pulp, is hid. Membranous opercula, or laminæ, are formed from the sides of the follicle, and, as seen in 5, meet over, leaving a lunated depression behind. The diagram, 5, supposing the opercula to be gently opened out, may be taken to represent a cross section through an incisor follicle 6. The lips of the groove also meet, except the lunated depression. 7. The opercula and lips of the groove cohere: the follicle becomes a closed sac (*s*); the papilla is the tooth-pulp (*p*), and has the shape of the crown of the future tooth; and the lunated depression becomes a cavity of reserve for the developement of the succedaneous permanent tooth: the saccular stage is now complete. The remaining figures, 8 to 12, show the commencement of the cap of the dentine on the pulp, the subsequent steps in the formation of the milk tooth, and its eruption through the gum (11); also the gradual changes in the cavity of reserve, the appearance of its laminæ and papilla, its closure to form the sac of the permanent tooth, its descent into the jaw, behind and below the milk-tooth, and the long pedicle (12) formed by its upper obliterated portion.

the pulp. About the termination of the third month, ossification begins, and a little sooner in the lower than in the upper jaw. This consists, at first, of a deposition of ivory matter on the surface of the pulp and at its top, which goes on increasing in width until it covers the whole of the dental pulp with a shell. It augments, also, in thickness at the expense of the dental pulp, which becomes gradually less and less. When the bony shell has extended as far as the neck of the tooth, the external membrane or sac of the tooth—for the follicle consists of two membranes—attaches itself closely, but not by adhesion, to the part. The inner membrane becomes much more vascular, and the *enamel* is secreted by it. A thickish fluid is observed to be poured out from the inner surface, which is soon consolidated into a dark, chalky substance, and afterwards becomes white and hard. At birth, the coronæ of the incisors are formed; those of the canine are not completed; and the molares have only their tubercles. The root or fang is formed last of all. As ossification proceeds, the corona of the tooth presses upon the gum, a portion of the follicle being interposed, which, as well as the gum, is gradually absorbed and the tooth issues.

The age at which the teeth make their appearance varies. The following table of the average periods, as stated by some of the principal writers on dental surgery, is given by Mr. Tomes.[1]

Authors.	Central Incisors. Months.	Lateral Incisors. Months.	Canines. Months.	1st Molar. Months.	2d Molar. Months.
Fox,	6, 7, 8	7, 8, or 9	17 to 18	14 to 16	24 to 30
	Extreme cases. 4 to 13				
Hunter,	7, 8, 9	7, 8, or 9	20 to 24	20 to 24	20 to 24
Bell,	5 to 8	7 to 10	14 to 20	12 to 16	18 to 36
Ashburner,	7th, lower jaw	9th, upper jaw	16, 17, 18		
	8th, upper jaw	10th, lower teeth	19 or 20		

Order of the First Dentition.

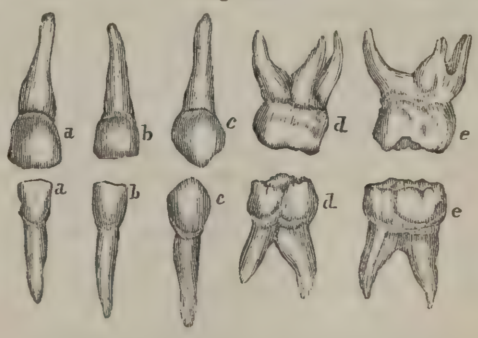
Authors.	Incisors. Central.	Incisors. Lateral.	Canines.	Molares. First.	Molares. Second.	
Sir R. Croft,	2	3	7	5	9	Upper jaw.
	1	4	8	6	10	Lower jaw.
Dr. Ashburner,	2	4	6	5	8	Upper jaw.
	1	3	7	5	8	Lower jaw.

Occasionally, children have been born with teeth, whilst in other cases they have not pierced the gum until after the period we are considering. Generally, the middle incisors of the lower jaw appear about the seventh month, and subsequently those of the upper; next the superior and inferior lateral incisors in succession; then the first lower molares, and first upper; next the inferior and superior canine teeth, successively: and lastly, the second molares of each jaw. As a general rule, the teeth of the lower jaw precede those of the upper: the lateral incisors are, however, an exception—those of

Fig. 511.

Front View of the Temporary Teeth.

Fig. 512.



The separate Temporary Teeth of each Jaw.

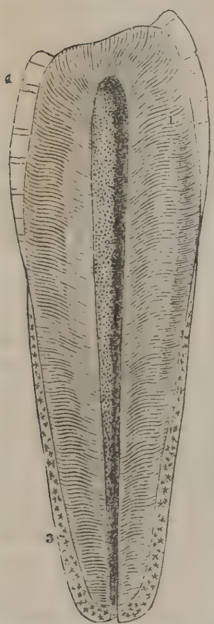
a. Central incisor. *b.* Lateral incisor. *c.* Canine. *d.* First molaris. *e.* Second molaris.

[1] A Course of Lectures on Dental Physiology and Surgery, p. 110, Lond., 1848.

the upper jaw making their appearance, in the majority of cases, before those of the lower. When the tooth passes through the dental capsule and integuments, the child is said to have "cut a tooth;" it would seem, however, to be a process of absorption rather than of disruption, as Mr. A. Nasmyth has suggested.[1]

The subject of the intimate anatomy and developement of the teeth has been investigated of late years by many observers, whose contributions are well worthy of study. Amongst the most important are those of Fränkel, Raschkow, Retzius, Arnold, Goodsir,[2] Owen, Nasmyth[3] and Tomes; and an able writer—Mr. Paget[4]—has remarked, that in no organs have the results of recent microscopic researches been so unexpected or brilliant. These researches have shown the teeth to be composed of three main constituents. 1. The *crusta petrosa*, *cementum* or *cortical substance*, which differs in its minute structure in no respect from common osseous tissue. It forms the outermost layer of the teeth; visibly surrounds the whole fang, and extends, according to Mr. Nasmyth, in a very thin layer over the enamel of the crown. 2. The *enamel*, or *adamantine substance* which invests only the crown of the teeth, and is composed of solid prisms or fibres about $\frac{1}{5600}$th of an inch in thickness, set side by side upright on the ivory; and, 3. The *dentine* or *ivory*, which forms the chief mass and body of the teeth, and is composed of a fibrous basis, traversed by very fine, branching, cylindrical tubuli, which run in an undulating course from the pulp cavity, on the interior of which they open, towards the adjacent part of the exterior of the tooth. The basis of the intertubular substance, according to Henle, is composed of bundles of flat, pale, granular fibres, the course of which is parallel to that of the tubules. Mr. Nasmyth,[5] however, states, as the result of his observations, that the so-called tubule is, in reality, a solid fibre, composed of a series of little masses succeeding each other in a linear direction, like so many beads collected on a string.

Fig. 513.



Vertical section of an Adult Bicuspis, cut from without inwards; greatly magnified.

1, 1. Ivory of the tooth, in which are seen the greater parallel curvatures, as well as the position of the main tubes. At the apex of the tooth the tubes are almost perpendicular. 2. Cavity of the pulp, in which are seen, by means of the glass, the openings of the tubes of the dental bone. 3, 3. Cortical substance which surrounds the root up to the commencement of the enamel. 4, 4. Enamel.

Dentition is necessarily a physiological process, but it is apt to be a cause of numerous diseases. The whole period of its continuance is one of great nervous

[1] Medico-Chirurg. Transactions, vol. xxii., and Op., infra cit., p. 113, Lond., 1849.

[2] Edinb. Med. and Surg. Journ., li.

[3] Researches upon the Developement and Structure of the Teeth, London, 1839 and 1841; and Mr. Robert Nasmyth, in Lond. and Edinb. Monthly Journ. of Med. Sci. Jan., 1843, p. 40.

[4] British and Foreign Medical Review, July, 1842, p. 270.

[5] Op. cit., p. 113, Lond., 1849.

susceptibility,—so that the surgeon never operates during it, unless when compelled; and we can understand, that the pressure exerted by the tooth on the gum, and the consequent inflammation and irritation, may lay the foundation for numerous diseases. More are doubtless ascribed to the process than it is entitled to, but still they are sufficiently numerous; and all require in their management the free division of the distended gum, so as to set the presenting part of the tooth at liberty. Whilst the teeth are appearing, the muscular structure of the body is acquiring strength, and the salivary organs are described by anatomists as becoming much more developed. The food of the child is now diversified, and it begins to participate in the ordinary diet of the table. The excrementitious matters are consequently altered in character, particularly the alvine, which become firmer, and acquire the ordinary fæcal smell; the urea is still, however, in the generality of cases, in less proportion than in the adult. The other functions require no special mention.

Figs. 514 and 515.

View of an Incisor and of a Molar Tooth, given by a Longitudinal Section, showing that the Enamel is striated and that the Striæ are all turned to the Centre. The internal Structure is also seen.

1. Enamel. 2. Ivory. 3. Cavitas pulpi.

The number of deaths, during this period, is great. The bills of mortality of London, as has been elsewhere remarked, show, that the deaths, under two years of age, are nearly thirty per cent. of the whole number. In Philadelphia, during a period of twenty years ending with 1826, the proportion was rather less than a third. The cholera of infants is the great scourge of our cities during the summer months, whilst in country situations it is comparatively rare; and it is always found to prevail most in crowded alleys, and in the filthiest and impurest habitations. There is something in the confined and deteriorated atmosphere of a town, which seems to act in a manner directly unfavourable to human life, and to the life of the young especially; and this applies also to the animal. Experiments were instituted by Dr. Jenner, and since by Dr. Baron,[1] which show that privation of free air and natural nourishment has a tendency to produce disorganization and death. Dr. Baron placed a family of young rabbits in a confined situation, and fed them with coarse green food, such as cabbage and grass. They were perfectly healthy when put up. In about a month, one of them died,—the primary step of disorganization being evinced by a number of transparent vesicles on the external surface of the liver. In another, which died nine days after, the disease had advanced to the formation of tubercles in the liver. The liver of a third, which died four days later, had nearly lost its true structure, so completely was it pervaded by tubercles. Two days afterwards, a fourth died; a number of hydatids was attached to the lower surface of the liver. At this time, Dr. Baron removed three young rabbits from the

[1] Delineations of the Origin and Progress of Various Changes of Structure which occur in Man, and some of the Inferior Animals, Lond., 1828.

place where their companions had died to another situation, dry and clean, and to their proper accustomed food. The lives of these were obviously saved by the change. He obtained similar results from experiments of the same nature performed on other animals.

c. *Third Period of Infancy.*

This requires no distinct consideration;—the growth of the child and activity of the functions going on as in the preceding period, but gradually acquiring more and more energy. Within this period, a third molar tooth appears, which is not, however, temporary, but belongs to the permanent set.

During the whole of infancy, the dermoid texture—skin and mucous membranes—is extremely liable to be morbidly affected; hence, the frequency of eruptive diseases, and of diarrhœa, aphthæ, croup, bronchitis, &c., many of which are of very fatal tendency. Owing, also, to the susceptibility of the nervous system, convulsions, hydrocephalus, and other head affections are by no means unfrequent.

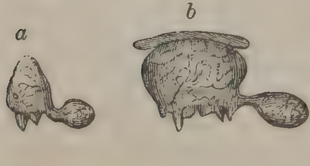
2. CHILDHOOD.

Childhood may be considered to extend from the seventh to the fifteenth year, or to the period of puberty; and it is particularly marked by the *shedding* of the first set of teeth, and the appearance of the second. It is manifest, that in the growth of the jaws with the rest of the body, the teeth, which, for a time, may have been sufficient in magnitude and number, must soon cease to be so; hence, the necessity of a fresh set, which may remain permanently. The process for the formation of the permanent teeth is similar to that of the milk or temporary teeth; yet it presents some remarkable points of difference and affords another surprising instance of the wonderful adaptation of means to definite objects, of which there are so many in the human body.

It is well described by Mr. Thomas Bell,[1] whose opportunities for observation have been unusually numerous, and whose zeal and ability in his profession, as well as in the prosecution of natural science, are well known.

The rudiments of the permanent teeth according to him are not original, and independent, like those of the temporary. They are derived from the latter, and continue, for a considerable time, attached to, and intimately connected with them. At an early period in the formation of the temporary teeth, the investing sac gives off a small process or bud, containing a portion of the essential rudiments, namely, the pulp covered by its proper membrane. This constitutes the rudiment of the permanent tooth. It commences in a small thickening on one side of the parent sac, which gradually becomes more and more circumscribed, and at length assumes a distinct form, though

Fig. 516.



a. Permanent Rudiment given off from the Temporary in an Incisor.
b. Permanent Rudiment given off from the Temporary in a Molaris.

[1] The Anatomy, Physiology, and Diseases of the Teeth, Lond., 1829; 2d Amer. edit., Philad., 1837.

still connected with it by a pedicle. For a time, the new rudiment is contained within the same alveolus as its generator, which is excavated by the absorbents for its reception. It is not, according to Mr. Bell, in consequence of the pressure of the new rudiment upon the bone, that this absorption is occasioned, but by a true process of anticipation; for he states, that he has seen, in the human subject—and still more evidently in the foal—the commencement of the excavation before the new sac was formed, and, consequently, before any pressure could have taken place on the parietes of the socket. The absorption does not, indeed, begin in the smooth surface of the socket, but in the cancelli of bone immediately behind it. By degrees, a small recess is thus formed in the paries of the alveolus, in which the new rudiment is lodged, and this excavation continues to increase with the increasing size of the rudiment; whilst, at the same time, the maxillary bone becomes enlarged, and the temporary tooth, advancing in its formation, rises in the socket. The new cell is thus gradually separated from the other, both by being itself more and more deeply excavated in the substance of the bone, and also by the formation of a bony partition between them, as seen in the marginal figure, 517, which exhibits the connection between the temporary tooth and the permanent rudiment, as it exists after the former has passed through the gum. As the temporary tooth grows and rises in the jaw, the connecting cord or pedicle elongates, and although the sac, from which it is derived, is gradually absorbed, it still remains attached to the neck of the temporary tooth. The situation of each permanent rudiment, when its corresponding temporary tooth has made its appearance through the gum, is deeper in the jaw and a little behind the latter, as represented in the marginal illustrations, (Figs. 518 and 519,) of the upper and lower jaw after the whole of the temporary teeth have passed through the gum. From these, it will be understood, how the upper part of the sac of the permanent rudiment, by means of the cord connected with the gum, gradually assumes the same relation to the gum as was originally sustained by the temporary rudiment.

Fig. 517.

Temporary Tooth and Permanent Rudiment.

Such is the view adopted by most odontologists. It is generally believed, that the sacs of the permanent teeth derive their origin from those of the milk teeth. Mr. Goodsir, however, maintains, and with much probability in favour of his view, that the two sets have an independent origin, and that each is developed in a distinct groove, (Fig. 510.) The cavity of reserve in which the permanent teeth are developed having been originally a process of the mucous membrane of the mouth; a rudiment of the communication sub-

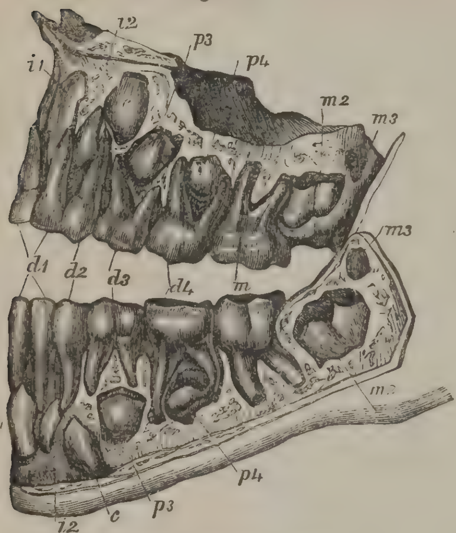
Fig. 518.

Temporary Teeth and Permanent Rudiments.

Fig. 519.

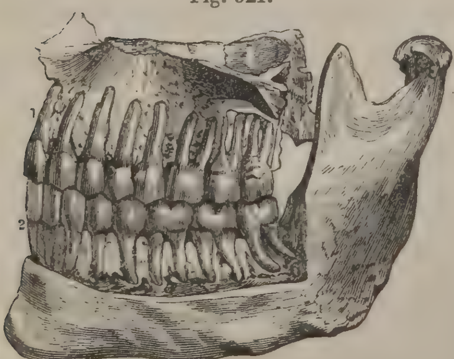
Temporary Teeth and Permanent Rudiments.

Fig. 520.



Deciduous and Permanent Teeth, æt. 7.

Fig. 521.



Side View of Upper and Lower Jaw, showing the Teeth in their Sockets. The outer Plate of the Alveolar Processes has been taken off.

1. First incisors of upper jaw. 2. First incisors of lower jaw.

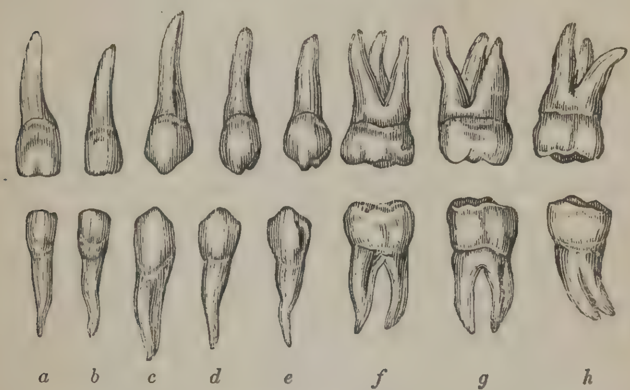
sists even until the eruption of the permanent teeth, under the form of the fibrous cord referred to above, which becomes a *gubernaculum* or guide,—an *iter dentis* or path for the tooth.

The ossification of the permanent teeth, for the incisors and first molaris, commences from the third to the sixth month after birth; about the ninth month, for the canine teeth; about three years, for the second molaris; at three years and a half, for the fourth; and, at ten years, for the fifth; but all this is liable to much variation.

The permanent teeth, during their formation, are crowded together in the jaw; but, as soon as they have advanced to a certain point, and can no longer be contained within their own alveoli, absorption of the anterior parietes of those cavities takes place, and the teeth are allowed to come in some measure forwards. In consequence of such absorption, it frequently happens, that not only the socket of the corresponding temporary tooth, but that of the tooth on each side is opened to the permanent one. Absorption of the root of the temporary tooth,—generally at the part nearest its successor,—now occurs, and this gradually proceeds as the latter advances, until the root is completely removed, when the crown falls off, leaving room for the permanent tooth to supply its place. It does not seem that this absorption of the

root is produced by pressure on the part of the permanent tooth, as it often happens, according to Mr. Bell, that the root of the temporary tooth is wholly absorbed, and the crown falls out spontaneously, long before the succeeding tooth has approached the vacant space. As a general rule, however, the actions must be regarded consentaneous; and Mr. Bell thinks, that this absorption resembles that, already referred to, for the formation of a new cell to receive a permanent pulp, and that it may be termed, like it, a "a process of anticipation." In both instances, the existence, though not the pressure, or even the contact, of the new body is necessary to excite the action of the absorbent vessels; and we, accordingly, find that in those cases, by no means unfrequent, in which the temporary teeth retain their situation in the mouth with considerable firmness until adult age, the corresponding permanent teeth have not been formed.

Fig. 522.



Upper and Lower Teeth.

a, a. Central incisors. *b, b.* Lateral incisors. *c, c.* Canine teeth. *d, d.* First bicuspidati. *e, e.* Second bicuspidati. *f, f.* First molares. *g, g.* Second molares. *h, h.* Third molares or *dentes sapientiæ.*

The following are the periods at which the permanent teeth generally make their appearance.

First molars,	7th year.
Central incisors,	8th "
Lateral incisors,	9th "
First bicuspids,	10th "
Second bicuspids,	11th "
Canines,	12th "
Second molars,	13th "
Third great molars, *dentes sapientiæ,*	17th to 20th.

When these have all appeared, the set is complete, consisting of thirty-two teeth, sixteen in each jaw,—the number of temporary teeth being only twenty. Fig. 521 represents the upper and lower permanent teeth in their alveoli or sockets, the external alveolar plate having been removed to show the mode in which they are articulated. Fig. 522 represents the same teeth when removed from the socket.

While the jaws are becoming furnished with teeth and increasing in

size, they undergo a change of form, and the branches become more vertical, so as to favour the exertion of force during mastication. When the teeth issue from the gums, they are most favourably situate for the act of mastication; the incisors are sharp, the canine pointed, and the molares studded with conical asperities; but, in the progress of age, they become worn on the surfaces that come in constant contact. During the occurrence of these changes, which embrace the whole of the period we are considering, and extend, at times, into the next two, the animal functions, especially that of sensibility, become surprisingly developed, and the intellectual and moral results of a well adapted system of education strikingly apparent. The nutritive functions are, likewise, performed with energy, the body not yet having attained its full growth; and, towards the end of the period, the organs of reproduction commence that developement, which has to be described presently.

The teeth appear with sufficient regularity to permit an inference to be drawn with regard to the age of the individual, and accordingly it has been proposed by Mr. Saunders[1] to make them a test for age in reference to the children employed in the factories of Great Britain. According to him, the ages between seven and thirteen may be estimated in this manner; and Mr. Tomes[2] remarks, that although he is not aware, that the assertions of Mr. Saunders have been backed by extended statistical research, he is prepared to corroborate their general correctness.

3. ADOLESCENCE.

The commencement of this age is marked by one of the most extraordinary developements, which the frame experiences; and its termination by the attainment of full growth in the longitudinal direction. The period of the former of these changes is termed *puberty;* that of the latter the *adult age.* The age of adolescence has been considered to extend from fifteen years to twenty-five, in men; and from fifteen to twenty-one, in women; but this is only an approximation, like the other divisions of the ages, all of which are subject to great fluctuation in individual cases. M. Flourens makes it from ten to twenty[3];—the latter being the period—he says—at which the epiphyses are united to the bones; and when this happens the body ceases to grow.

During the periods we have considered, no striking difference exists in the appearance of male and female, except as regards the generative organs; but, about the age of puberty, essential changes occur, that modify the characteristics of the two sexes in a manner, which they maintain through the remainder of existence; and these changes affect the whole economy to a greater or less degree. In the male, the skin loses more or less of its delicacy and whiteness; the hair becomes darker; the areolar tissue condensed, and the muscles more bulky, so that they are strongly defined beneath the surface; the beard appears,

[1] The Teeth, a Test for Age, considered with reference to the Factory Children, addressed to the Members of both Houses of Parliament, Lond., 1837. See, also, Mr. A. Nasmyth, Researches on the Developement, &c., of the Teeth, p. 159, Lond., 1849.

[2] A Course of Lectures on Dental Physiology and Surgery, p. 118, London, 1848.

[3] De la Longévité Humaine, &c., 2de édit., p. 46, Paris, 1855.

as well as hair upon the pubes, chest, and in the axillæ. The different parts of the body become developed in such manner that the centre of the frame now falls about the pubes. The encephalon has increased in size, and has become firmer. The ossification of the bones, in the direction of their length, terminates towards the end of the period. The muscles become more red and fibrinous, losing the gelatinous character they previously possessed; and, in the animal, exhibiting those striking changes which we see—from veal to beef, from lamb to mutton, &c. The larynx undergoes great augmentation, and the glottis particularly is elongated and widened. The jaws complete their growth, and the dentes sapientiæ appear so as to make up the full complement of sixteen teeth in each jaw. The changes in the nutritive organs are not great, consisting chiefly in their developement to correspond with the increased size of the frame. The greatest modification occurs in the organs of reproduction, which are now in a state to exercise their important functions. The testicles, at puberty, suddenly enlarge so as to attain twice the diameter they previously possessed; and the secretion of sperm is accomplished. The penis is also greatly increased in size; and, according to M. Adelon,[1] "becomes susceptible of erection." The susceptibility, however, exists long before this age. It may be noticed even in the first period of infancy. The scrotum assumes a deeper colour. Such are the chief changes that supervene in the male.

In the female, they are not quite so striking;—the general habit remaining much the same as during childhood. The skin preserves its primitive whiteness; and, instead of the areolar tissue becoming more condensed, and the muscles more marked, as in the male, fat is deposited in greater quantity between the muscles, so that the form becomes more rotund. Hair appears on the organs of reproduction and in the axillæ, whilst that of the head grows more rapidly. The developement of the genital organs is as marked as in the male. The ovaries attain double their previous dimensions; the uterus enlarges; and a secretion takes place from it which has been elsewhere described—the *menstrual flux;* the mons veneris and labia pudendi are covered with hair; the labia enlarge and the pelvis has its dimensions so modified as to render labour practicable. At an early age, the long diameter of the brim is from before to behind; but it is now in the opposite direction, or from side to side; and the bosom, which prior to this age, could scarcely be distinguished from that of the male, becomes greatly developed; fat is deposited so as to give the mammæ their rotundity; the mammary gland is enlarged; and the nipple of greater size;—changes fitting the female for the new duties which she may be called on to exercise.

The functions undergo equally remarkable modifications, under the new and instinctive impulse that animates every part of animal life. The external senses attain fresh, and peculiar activity; the intellectual faculties become greatly developed, and this is the period in which the mental character is more improved by education than any other. It embraces, indeed, the whole time of scholastic application to the higher studies. Prior to the end of the period, the male youth enters upon the avocation which is to be his future support, and both sexes may become established in life in the new relations of husband and wife

[1] Physiologie de l'Homme, 2de édit., iv. 448, Paris, 1829.

and of parent and child. It is during this age, that an indescribable feeling of interest and affection is experienced between the sexes; and that the boldness of the male contrasts so strikingly with the captivating modesty of the female,—

> "That chastity of look, which seems to hang
> A veil of purest light o'er all her beauties."

The muscles having acquired their strength and spring, the severer exercises are now indulged, and mechanical pursuits of all kinds,—military and civil,—are undertaken with full effect. The expressions participate in the altered condition of the mental and moral manifestations, and indicate vivacity, energy, and enthusiasm. The voice of the male acquires a new character, and becomes graver, for reasons assigned elsewhere; whilst that of the female experiences but slight modification. The nutritive functions of digestion, absorption, and respiration experience little change; but nutrition, strictly so called, is evidently modified, from the manifest difference in the developement and structure of the various organs. The muscles contain more fibrin; the blood is thicker and richer in red corpuscles; and the excretions manifest a higher degree of animalization. Urea has taken the place of benzoic acid in the urine; and the cutaneous transpiration has lost its acidulous smell, and become rank and peculiar. Lastly, the sexual functions are now capable of full and active exercise, and appear to be intimately connected with the energy and developement of many parts of the economy. If the genital organs do not undergo the due change at puberty, or if the testes of the male or the ovaries of the female be removed prior to that age, considerable changes occur. These are more manifest in the male, inasmuch as the ordinary changes, that supervene at puberty, are in him more marked than in the female. The removal of the testicles, prior to puberty, arrests those changes. The beard does not appear, nor the hair in the axillæ nor on the pubes, as in the entire male; and if those animals in which the males are distinguished by deciduous horns, as the stag,—or by crests and spurs, as the cock,—be castrated before their appearance, such appendages do not present themselves. If, however, they be castrated after puberty, they retain these evidences of masculine character. The eunuch, likewise, who becomes such after the appearance of the beard, preserves it, although to a less extent than usual. The developement of the larynx is arrested by castration, so that the voice retains, with more or less change, the treble of the period prior to puberty; hence this revolting operation has been had recourse to for the sake of gratifying the lovers of music.

In the course of age, we find that, during the progressive evolution of the organs, one set is liable to morbid affections at one period, and a different set at another. In early age, the mucous membranes and the head are especially liable to disease; and, at the period we are now considering, affections of the respiratory organs become more prevalent. It is indeed the great age for pulmonary consumption,—that fatal malady, which, Sydenham supposed, destroys two-ninths of mankind. In the female, whose proper feminine functions do not appear at the due time, or are irregularly exercised, the commencement—indeed the whole of this period—is apt to be passed in more or less sickness and suffering.

4. VIRILITY, OR MANHOOD.

M. Hallé has divided this age into three periods,—*crescent*, *confirmed*, and *decrescent virility*.[1] The *first* of these extends from twenty-five to thirty-five in the male, and from twenty-one to thirty in the female; the *second* from thirty-five to forty-five in the male, and from thirty to forty in the female. Neither of these will require remark, the whole of the functions throughout this work,—when not otherwise specified,—being described as accomplished in manhood. Owing to the particular evolution of organs, the tendency is not now so great to morbid affections of the respiratory function. It is more especially the age for cephalic and abdominal hemorrhages; accordingly, apoplexy and hemorrhoidal affections are more frequent than at any previous period.

In *decrescent virility*,—in which M. Hallé comprises the period of life between forty and fifty in the female, and between forty-five and sixty in the male,—signs of decline are often manifest. The skin may become shrivelled and wrinkled; the hair gray, or white and scanty; the teeth worn at the top, chipped, loose, and many perhaps lost. The external senses, especially the sight, are more obtuse, partly owing to a change in the physical portions of the organ, so that powerful spectacles become necessary, and partly owing to blunted nervous sensibility. Owing to the same cause, the intellectual faculties may be exerted with less energy and effect, and the moral manifestations be more feeble and less excitable. Locomotion is less active, owing to diminution in the nervous power, as well as probably to physical changes in the muscles, so that the individual may begin to stoop,—the tendency of the body to bear forwards being too great for the extensor muscles of the back to counteract. The expressions participate in the condition of the intellectual and moral acts, and are, consequently, less exerted than in former periods. The nutritive functions do not exhibit any very remarkable change, and may even remain active to a good old age. The functions of reproduction show the greatest declension, especially in the female. The male may preserve his procreative capabilities much longer than this period; but in the female the power is usually lost, the loss being indicated by the cessation of menstruation. After this, the ovaries shrivel, the uterus diminishes in size; the breasts wither; the skin becomes brown and thick; long hairs appear on the upper lip and chin, and all the feminine points are lost that were previously so attractive. The period of the cessation of the menses is liable to many different disorders, which are the source of much annoyance, and are, at times, attended with fatal consequences. Prior to their total disappearance, they often become extremely irregular in their occurrence, sometimes returning every fortnight; debilitating by their frequency, and by the quantity of the fluid lost, and laying the foundation for uterine or other diseases of a serious character. Cancerous affections of the mammæ or labia, which had been previously dormant or not in existence, now appear, become developed, and at times with extreme rapidity. In consequence of the great liability to such affections, this has been called the *critical age*, *critical period* or *critical*

[1] M. Flourens considers the *first youth* to extend from twenty to thirty; and the *second* from thirty to forty. The *first virile age* he makes from forty to forty-five; and the *second* from fifty-five to seventy. De la Longévité Humaine, &c., 2de édit., p. 46, Paris, 1855.

time of life or *turn of life.* The danger to the female is not, however, so "critical" at this period as the epithet might suggest,—the statistical researches of M. de Chateauneuf and of Lachaise, Finlaison,[1] and others having shown, that between the ages of forty and fifty no more women die than men. M. Constant Saucerotte has, indeed, attempted to show by statistics on a great scale, that the mortality amongst women is greater between thirty and forty than between forty and sixty; and Muret, from his Statistics of the Pays du Vaud, did not find between forty and fifty a more critical period than between ten and twenty.[2]

5. OLD AGE.

This is the age when every thing retrogrades. It is the prelude to the total cessation of the functions, where the individual expires—which is but rarely the case,—from pure old age. This period has been divided into three stages:—*incipient* or *green old age*, reaching to seventy years; *confirmed old age* or *caducity*, to eighty-five years; and *decrepitude*, from eighty-five years upwards. M. Flourens[3] makes the *first* or *green old age* commence at seventy, and extend to eighty-five; and to this succeeds the *second* and *last old age.*

In *incipient* or *green old age*, the declension that had occurred in the period of *decrescent virility*, is now more evident. The intellectual and moral manifestations may exhibit more marked signs of feebleness; and the muscular powers totter, and require the aid of a support—as well to convey a part of the weight of the body to the ground, as to enlarge the base of sustentation. The muscles of the larynx may participate in the general vacillation; the

> "Big manly voice,
> Turning again towards childish treble, pipes
> And whistles in the sound,"

and is broken and tremulous.

The appetite is great, and the powers of digestion are considerable; but mastication is largely deteriorated. In the first place, the teeth may fall out, in consequence of the constant deposition of fresh layers in the dental cavities, which ultimately close them, and obliterate the vessels that pass to the internal papillæ for their nutrition. As soon as the teeth are lost, the alveolar processes, which supported them, waste away by absorption, and the depth of the jaw is

Fig. 523.

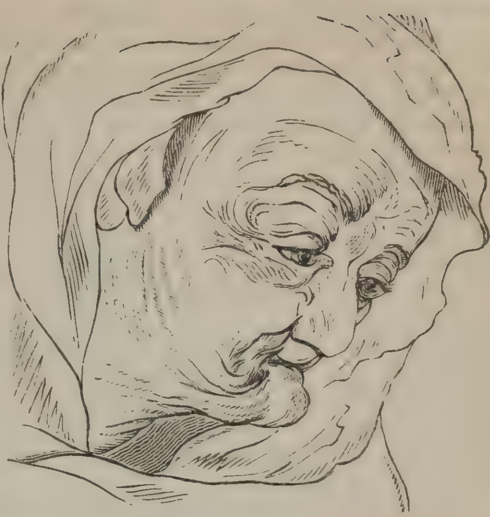
Skull of the Aged.

[1] Reports on the Evidence and Elementary Facts on which the Tables on Life Annuities are Founded, Lond., 1829.

[2] Churchill, Outlines of the Principal Diseases of Females; American Medical Library edit., p. 82, Philad., 1839; or edit. by Dr. Condie, Philad.

[3] Loc. cit.

Fig. 524.



Physiognomy of the Aged.

thus greatly lessened. On these accounts, the jaws only approach each other at the forepart; the chin projects, and the angle of the jaw is thrown more forward. As the teeth and the sockets disappear, the alveolar margins become thin and sharp, and the gum hardens over them; the chin and nose necessarily approach (Figs. 523 and 524); the lips fall in, and the speech is inarticulate. We can thus understand the peculiarities of the mastication of the aged. They are compelled to bite with the anterior portions of the jaws; for which reason as well as owing to the greater obliquity of the insertion of the levator muscles of the lower jaw, but little force can be exerted; and owing to the too great size of the lips, the saliva cannot be retained. Respiration is not as readily accomplished, partly owing to the complete ossification of the cartilages of the ribs, but chiefly to diminished muscular powers. The valves of the heart and many of the blood-vessels, especially of the extremities, become more or less ossified, and the pulse is somewhat slow and intermittent, but generally perhaps faster than in the adult. Of 255 women, between the ages of 60 and 96, examined by MM. Hourmann and Dechambre,[1] the average number of pulsations in the minute was 82·29; of respirations, 21·79. Nutrition is effected to such a degree only as to keep the machine in feeble action; and animal heat is formed to an inadequate extent, so that the aged require the aid of greater extraneous warmth: in many cases, the powers of reproduction in the male are completely lost.

In *confirmed old age*, the debility of the various functions goes on augmenting. The mental and corporeal powers almost totter to their fall; and frequently a complete state of dementia or dotage exists. Often, however, we are gratified to find full intellectual and moral enjoyment prevailing even after this period, along with the possession of considerable corporeal energy. The author had the honour to enjoy the friendship of three illustrious individuals of this country, two of whom had filled the highest office in the gift of a free people, all of whom are now no more; each of these gentlemen exhibited, after the lapse of eighty-two summers, the same commanding intellectual powers and the same benevolence that ever distinguished them.

In this stage, locomotion becomes more difficult; the appetite is

[1] Archiv. Général. de Médec., 1825.

considerable, and the quantity eaten at times prodigious,—the digestive powers being incapable of separating the due amount of chyle from a quantity of aliment that was sufficient in the previous ages. Difficulty, however, sometimes arises in defecation, the muscular powers being insufficient to expel the excrement. From this cause, accumulations occasionally take place in the rectum, which may require the use of mechanical means,—as injections, the introduction of an instrument to break them down, &c. Generation is, usually, entirely impracticable, erection being impossible; and during the whole of this and the next stage, the urinary organs are liable to disorder,—irritability about the neck of the bladder, and incontinence of urine, being frequent sources of annoyance.

The density of the lungs, together with the quantity of blood they admit, diminishes with the progress of age; the thorax itself is gradually accommodated to the change; it becomes atrophied as the lungs are atrophied; it contracts as they contract, and the diminution in their vascularity, which is always in a ratio with the diminution of structure, shows the direct proportion between the lessened chemical and mechanical actions.[1]

Finally, to this stage succeeds that of *decrepitude*, so well described by Shakspeare:—

> "Last scene of all,
> That ends this strange, eventful history,
> Is second childishness, and mere oblivion;
> Sans teeth, sans eyes, sans taste, sans everything."
> As You Like It, ii. 7.

The loss of power, mental and corporeal, becomes progressively greater; and, in addition to the abolition of most of the external senses—especially those of sight and audition—the intellectual faculties are, perhaps, entirely gone; all muscular motion is lost, and paralysis requires constant confinement to the bed, or easy chair; the excretions are passed involuntarily; sensibility becomes gradually extinct, and life finally flits away as imperceptibly as the twilight merges in the shades of night; "nec subito frangitur; sed diuturnitate extinguitur."

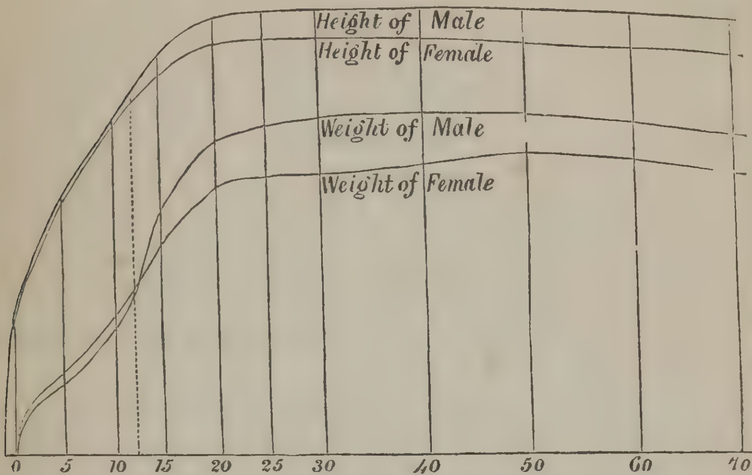
M. Quetelet[2] has deduced from extensive observations the relative heights and weights of both sexes at different periods of existence. The results are exhibited in the diagram. (Fig. 525). The increase in height is most rapid in the first year, and afterwards diminishes very gradually; between the ages of 5 and 16, the annual increase is very regular. The difference between the height of the male and female at birth continues to augment during infancy and growth; but it is not very marked until about the 15th year, after which the female grows at a diminished rate; whilst the male goes on in nearly the same degree until about the age of 19. The female, consequently, arrives at her full height earlier than the male;—the full height of the latter not being generally attained until about the age of 25. At

[1] Magendie, and MM. Hourmann and Dechambre.

[2] Annales d'Hygiène Publique, vi. 89; and in his work, Sur l'Homme et le Développement de ses Facultés, Bruxelles, 1835; or translation of the same, p. 63, Edinb., 1842.

about 50, both sexes experience a diminution of stature, which continues during the latter part of existence. The average height of the male and female who have attained their full developement is about $3\frac{1}{4}$ times that of the new-born infant of the sexes respectively. The relative weight of the sexes corresponds pretty nearly with the height.

Fig. 525.



Curves indicating the Developement of the Height and Weight of Male and Female at Different Ages.

The preponderance exhibited by the male at birth increases gradually during the first few years; but towards the period of puberty the proportional weight of the female increases; and about the age of 12 there is little difference between the sexes. After this, however, the weight of the male increases much more rapidly, especially between 15 and 20; subsequently, there is not much increase on the part of the male, although his maximum is not attained until the age of 40; whilst there is an absolute diminution on the part of the female, whose weight remains less during nearly the whole period of child-bearing. After this, however, her weight again experiences an increase, and its maximum is attained about 50. In old age, the weight of both sexes undergoes a diminution in nearly the same degree. The average weight of the male and female who have attained their full developement is twenty times that of the new-born infant of the sexes respectively.

Such is a brief description of the chief changes that befall the body in the different ages. To depict them more at length would be inconsistent with the object and limits of this work. It is clear, that, although the divisions, which we have adopted from Hallé, are entirely arbitrary,—must run into each other, and be liable to numerous exceptions,—certain well-marked changes occur about the commencement or termination of many of them, and a singular diversity takes place in the successive evolution of organs; whilst some are predominant at one time, they fall behind others at a previous or

subsequent period; and such changes may lay the foundation for morbid affections in certain organs at one age, which do not prevail at another. The ancients, who believed that great mutations occur at particular intervals,—every three, seven or nine years, for example, as the particular number might be at the moment in favour,—compared these periods to knots uniting the different stages of life, and giving the economy a new direction. These knots they called the *climateric* or *climacteric years*, and they conceived the body to be especially liable to disease at the periods of their occurrence. The majority assigned them to the number seven and its multiples; and the fourteenth and twenty-first years especially were conceived to be replete with danger. Others applied the term *climacteric* to years resulting from the multiplication of seven with an odd number, and especially with nine; the sixty-third year being regarded, by almost all, as the *grand climacteric.* The error with the ancients lay in considering that numbers exerted any agency. Every one admits the influence of particular evolutions on health; and, at the present day, the word *climacteric* is generally restricted to certain periods of life, at which great changes supervene, independently of any numerical estimate of years;—such as the period of puberty in both sexes;—that of the cessation of the menses or the critical time of life in the female, &c.

It need hardly be remarked, that the different ages described, instead of extending through the protracted period of eighty-five years and upwards, may be varied by original constitution, climate, habits of life, &c., so that the stages may be shorter than usual, and all the signs of decrepitude occur many years earlier; and, on the other hand, the period of decrepitude may, through strength of original conformation, and other causes, be largely postponed.

CHAPTER II.

SLEEP.

THE difference between the two classes of animal and nutritive functions is strikingly exhibited in the phenomena we have now to consider. Whilst the former are more or less suspended, the latter continue their action with but little modification. The functions of sensibility, voluntary motion, and expression cannot be indulged for any length of time, without fatigue being induced, and a necessity arising for the reparation of the nervous energy expended during their action. After a time,—the length of which is somewhat influenced by habit,—the muscles have no longer power to contract, or the external senses to receive impressions; the brain ceases to appreciate; mental and moral manifestations are no longer elicited; the whole of the functions of relation become torpid, and remain in this state until the nervous system has been renovated, and adapted for the repetition of those functions, which, during the previous waking condition, had been exhausted. This state constitutes *sleep;* which, consequently, may be defined—the periodical and temporary suspension of all, or most, of those functions that connect us with the universe. The sus-

pension occurs in those functions and in those only; and hence the consideration of sleep, in many physiological treatises, has immediately followed that of the functions of relation. The nutritive functions continue regularly in action from the earliest period of fœtal formation; before mental manifestations exist in the embryo, and during sleep. For them there is no cessation, and scarcely any declension of activity, until the decadency of the frame affects them along with the whole of the machinery. Sleep, in the language of poetry, has been compared to death; and Dr. Good[1] has stated, that the resemblance between them is not less correct upon the principles of physiology, than it is beautiful among the images of poetry. "Sleep is the death or torpitude of the voluntary organs, while the involuntary continue their accustomed actions. Death is the sleep or torpitude of the whole." Physiologically, the difference appears to us considerable. During the whole of sleep a process of renovation is going on in the organs of animal life, which adapts them for subsequent activity, and contrasts signally with the state of annihilation that constitutes death; hence the important difference between healthy sleep, and the state of coma induced by any morbid cause, from which the patient is aroused languid and exhausted, instead of active and recruited. The fœtus in utero is described by some as in a perpetual sleep, until aroused by the new actions established at birth; but even in this case there must be alternations of activity and suspension in the nervous functions. We have seen elsewhere, that they are manifestly more or less exerted during intra-uterine existence; nervous energy must therefore be expended; and renovation,—to a much less extent, it is true, than in the new-born child,—be necessary. Linnæus,[2] under the term *somnus plantarum*, comprehends a peculiar state in the constitution of many plants during the night, as evinced by a change of position, generally a drooping or folding together of their leaves or leaflets; such a change being occasioned by the withdrawal of the stimulus of light, and, probably, it has been conceived, constituting a state of rest to their vital functions; but it is obvious, that there can be no similitude between this condition and that of the sleep of animals, which is confined to the functions of relation,—functions that do not even exist in the vegetable.

The approach of sleep is indicated by signs, that are unequivocal, and referable to the encephalon. The great nervous centre of animal life feeling the necessity for rest and renovation, an internal sensation arises in it, as well as in the whole of the nervous system over which it presides, termed *sleepiness* or the *sensation* or *want* or *desire of sleep*, which, provided the waking state has been protracted, ultimately becomes irresistible, and often draws on sleep in spite of every effort to the contrary. It is affirmed, that boys, exhausted by exertion, dropped asleep amid the tumultuous noise of the battle of the Nile; and the fatigued soldier has often gone to sleep amid discharges of artillery. An engineer has been known to fall asleep within a boiler whilst his fellows were beating it on the outside with their heavy hammers.

[1] Book of Nature, 3d edit., ii. 203, Lond., 1834.
[2] Amœnitat. Academ., tom. iv.

Noises will at first prevent sleep, but the desire is ultimately so invincible, that they cease to produce any effect. In the noisy inns of large towns, where the perpetual arrivals and departures of travellers keep up an incessant din and confusion, sleep may be for a time withheld, but it ultimately supervenes, although the tumult may be even tenfold; and if the noise should, from any cause, suddenly cease, the individual will probably awake. It is reported of the proprietor of some vast iron-works, who slept close to them, notwithstanding the noise of sledge-hammers, forges, and blast-furnaces, that he would immediately awake if any interruption occurred during the night. This effect of habit is seen in the infant, which has been accustomed to the cradle. The moment the motion and noise of the cradle, or the sound of the nurse's voice—if she has been in the custom of singing the child to sleep—ceases, it awakes.

When the desire for sleep sets in vigorously, the animal functions become more obtuse, until they progressively fail to be exerted. The cessation does not occur in all simultaneously. The power of volition is gradually lost over the muscles; the eyes cannot be kept open; the upper eyelid falls, and if we attempt to raise it again, it appears to be weighed down; the eyeball is directed upwards, and the pupil is contracted; the arms fall where gravity would take them; the extensor muscles of the back, deprived of volition, cease to contract, and the head falls suddenly forward, occasioning *nodding*, which rouses the brain to momentary action, to be again lost, however. If the individual be in the erect attitude, his limbs bend under him; and if sitting, the head gradually falls upon the chest; the extensors of the trunk no longer contract with sufficient force to obviate its tendency to fall forwards; and the attitude, unsupported, cannot be maintained. The same gradual suspension occurs in the muscular movements concerned in speech and in the production of voice, which becomes feeble, confused, broken, and ultimately lost. In short, all the strictly voluntary muscles have their action suspended,—the levator palpebræ superioris among the rest; and the eye is closed by the action of the orbicularis palpebrarum, which is under the reflex system of nerves.

If we determine to resist the desire for sleep, we yawn and stretch, for reasons elsewhere assigned, and endeavour to arouse the functions to renewed activity. If the state of wakefulness has not been long protracted, we may be successful; but all our endeavours fail, if the nervous system be so far exhausted as to render reparation indispensable. From the commencement of sleepiness, the action of the senses is enfeebled, and gradually suspended. The sight yields first,—the closure of the eyelids preventing the organ from being impressed by its special irritant. Smell yields after taste; hearing after smell; and lastly, touch sleeps; although the appropriate irritants may continue to reach the organs of those senses. All the internal sensations, hunger, thirst, &c., as well as the morbid sensation of pain, are no longer appreciated. The intellectual and moral manifestations exhibit, from the commencement of the feeling of heaviness, the languor that pervades the frame. The will gradually ceases to control the functions under its dominion, until ultimately the power of volition is lost. In the less perfect kind of sleep or in *slumber*, the ideas flit in a disorderly

manner, constituting a kind of delirium; but when sleep is complete, the whole encephalic organ appears to be at rest, and perceptions are no longer accomplished: special irritants may be applied to the external senses, but they excite no sensation. Many physiologists affirm, that the internal functions of nutrition acquire more energy during sleep; but M. Broussais[1] disputes the affirmation, and maintains, that the want of action in the senses, muscles, and intellect, must necessarily occasion diminished energy in the nutritive functions. During sleep, circulation and respiration appear to be retarded; but in thirty-seven cases of induced or "mesmeric sleep, observed by Professor J. K. Mitchell; the pulse before sleep was, on the average, 81·7; during sleep 105; the respiration before sleep 19·04; during sleep, 19·68; so that, whilst the pulse is always quickened, the respiration is but little affected. The proportion of the pulse to the respiration was 4 to 1 in the waking condition, and nearly 5 to 1 in the sleeping.[2]

In normal sleep, perspiration is less active, and digestion more tardy than in the waking condition. The difference in the last respect is so great, that, as M. Broussais remarks, the appetite recurs many hours before the usual time where long watching is indulged, and an additional meal becomes necessary; proving the truth of the old French proverb,—"*qui dort dine*"—"who sleeps dines." Secretion, nutrition, and calorification are also less energetically performed than usual. Absorption alone, according to some, is more active; but there seems not to be sufficient reason even for this assertion. The notion of the greater activity of the nutritive organs is as old as Hippocrates, and has been acquiesced in by almost all subsequent writers without examination, especially as it seemed to show a kind of alternation and equipoise between the respective periods of activity of animal and organic life.

If we examine into the condition of the nervous system during sleep, we find, that the division, which presides over sensation, volition, and the mental and moral manifestations—the animal functions, or those of relation, in other words—has its action temporarily suspended; whilst the vital and nutritive functions that are carried on under the reflex and sympathetic systems never sleep: respiration, a phenomenon of reflex nervous action, never rests from the commencement of existence to its final cessation. The body generally remains in a state of semi-flexion, the one which, as we have elsewhere seen, requires least natural effort. To this, however, there are numerous exceptions depending upon habit. Perhaps the easiest position for the body is on the back. It is that assumed in extreme debility, when the prostration is so great that the individual sinks down in the bed like a dead weight; but the extensor muscles of the thigh and leg, under such circumstances, become fatigued; and relief is obtained by drawing the feet upwards so as to elevate the knees. This is a common attitude in the most debilitating maladies, and is often maintained until within a short time prior to dissolution.

Sleep can persist with the exercise of certain muscles. Couriers, on

[1] Op. citat., p. 183.
[2] S. Weir Mitchell, Amer. Journ. of the Med. Sciences, April, 1854, p. 387.

long journeys, nap on horseback; and coachmen on their boxes. The author has seen a servant boy erect and asleep in the intervals between the demand for his services at table. During the first sleep, the suspension of the animal functions is most complete; but, towards morning, some of them become less asleep, or more excitable than others. The intellectual and moral faculties are frequently inordinately active, giving occasion to dreams, which, with some individuals, occupy a great portion of the period allotted to rest. The sense of tact, too, is easily roused. If we lie in a position that is disagreeable, it is soon changed; the limbs are drawn away, if irritated in any manner; the bedclothes are pulled up, if the air be disagreeably cold, &c. The sense of sight and the voluntary motions are least readily aroused; so that those functions, which fall asleep the last, are most easily awakened, and they gradually resume their activity in the order in which they lost it. After six or eight hours of sleep,—more or less according to circumstances,—the individual awakes, not generally at once, however; a state of slumber, like that which preceded sleep, now succeeding it. The organs, which are the last to resume their activity, require to be excited to the performance of their functions. The eyes are rubbed; stretching is indulged, which recalls the nervous influx to the muscles; and sighing and yawning arouse the muscles of respiration; and compensate, in some measure, for the minor degree of aeration of the blood accomplished during sleep. The urine is discharged, and the phlegm, which may have collected in the air-passages, is expectorated: these excretions accumulate during sleep, because, owing to diminished sensibility, the call for their evacuation is not as urgent. In cases of catarrh accompanied by copious mucous secretion, and in phthisis pulmonalis, the fluid collects in surprising quantity in the air-passages during sleep, and is expectorated as soon as the brain is sufficiently aroused to respond to the sensation.

When the individual is fully awake, the energy with which the animal functions are exercised exhibits that the nervous system must have entirely recruited during its state of comparative inaction. The period of sleep necessary for this purpose varies in different individuals, and at different ages. Some require eight or ten hours; others not more than three or four; and others are said to have been contented throughout the course of a long life with not more than one or two. Men of active minds, whose attention is engaged in a series of interesting employments, sleep much less than the lazy and listless. General Pichegru informed Sir Gilbert Blane,[1] that in the course of his active campaigns he had, for a whole year, not more than one hour of sleep, on an average, in the twenty-four hours. Frederick of Prussia and Napoleon are said to have spent a surprisingly short time in rest; but with respect to the latter, the fact is controverted by one,[2] who had excellent opportunities for observation. It is probable, that in these cases the sleep is more intense, and that such of the animal functions as indispensably require rest are completely suspended during the whole period assigned to it. These are the functions of voluntary

[1] Medical Logic, 2d edit., p. 83.
[2] Bourienne, Private Memoirs of Napoleon Bonaparte, Amer. edit., Philad., 1831.

motion more particularly; the intellectual and moral faculties requiring a much shorter period of repose, as is manifest by their incessant activity during dreaming,—a condition which, with some, continues through almost the whole night. The same individual, too, will spend a shorter time in sleep, when strongly interested in any pursuit, than in the monotonous occurrences of ordinary life; and, when any subject occupies us intently, it will frequently keep us awake in spite of ourselves; but although the period of sleep may be protracted much beyond the accustomed hour by unusual excitement, the effect of the stimulus becomes insufficient, and sleep comes on under circumstances, which appear most unfavourable to it. The lunatic affords us a wonderful example of powerful resistance to sleep and fatigue, or rather of the short period, which is necessary for the renovation of the nervous system, kept almost incessantly upon the stretch, as it is in many of these distressing cases. In like manner, the sufferer from ill health, loss of property or kindred, resists at times the recurrence of sleep to a degree that excites surprise; and according to a recent writer[1] this want of sleep is the most frequent and immediate cause of insanity: on the other hand, a distinguished physiologist[2] regards too prolonged sleep as the cause of idiocy or madness. It has been a common remark, that women require more sleep than men, and Mr. Georget[3] assigns them a couple of hours more,—allotting to men six or seven hours, and to women eight or nine; but Dr. Macnish[4] judiciously doubts, whether the female constitution requires more sleep than the male: at least, he says, it is certain, that women endure protracted wakefulness better than men, "but whether this may result from custom is a question worthy to be considered." The fact is, however, too general to allow custom to be invoked. It would seem, indeed, that the female frame, although far more excitable than that of the male, is longer in having that excitability exhausted, and that the recuperative powers are greater, so that, when exhausted, it is more readily restored. The notion, that the female needs more rest than the male, appears to be traditionary, and like most traditions, to have been handed down from one individual to another without due examination. The degree of muscular and mental exertion, to which the male is accustomed, would seem to indicate that a longer period of rest ought to be required by him to admit of the necessary restoration of excitability. In infancy and youth, where the animal functions are extremely active, the necessity for sleep is greatest; in mature age, where time is more valued and cares are more numerous, it is less indulged; whilst the aged may be affected in two opposite ways; they may be either in a state of almost constant somnolency, or their sleep may be short and light.

Sleep has been divided by the physiologist into *complete* and *incomplete.* The former is characterized by a suspension of all the animal functions;—a state, the existence of which has been doubted by many. Certain it is, that it can occur but rarely, and only when all the organs have stood in equal need of rest and renovation; and when none have

[1] Brigham, American Journal of Insanity for April, 1845, p. 319.
[2] Magendie, Précis de Physiologie, vol. ii., Paris, 1825.
[3] Physiologie du Système Nerveux, &c., Paris, 1821.
[4] Philosophy of Sleep, Amer. edit., p. 280, New York, 1834.

preserved, from the preceding state of waking, a peculiar susceptibility for action. The nearest approach to it occurs in the first hours of repose; after which, it becomes incomplete; some of the functions are not equally sound asleep, and consequently respond to excitants with different degrees of facility; and the various organs do not require the same time for reparation, and therefore awake at different intervals; hence dreams arise, which occur chiefly towards morning, or after the sleep has become incomplete; that is, when some of the animal functions are more or less actively, but irregularly, exercised.

1. DREAMS.

Anciently, dreams were regarded as supernatural phenomena, under the control of the children of Somnus or Sleep,—Morpheus, Phobetor, or Icelos, and Phantasos. These three children, according to Ovid,[1] were capable of transforming themselves into any shape; the employment of Morpheus being to counterfeit the forms of men; Phobetor to assume the likeness of brutes and objects of terror: and Phantasos that of inanimate creatures. For a long time dreams were supposed to reveal future events by types and figures: as when Hecuba dreamed she had conceived a firebrand; and Cæsar that he should lie with his mother, which was interpreted that he should enjoy the empire of the earth,—the common mother of all living creatures. Oneiromancy was an encouraged art, and ministered largely to the credulity and superstition of the people. Strange to say, there are yet those who look upon dreams to be typical and instructive, and consequently supernatural! Mr. Baxter[2] and Bishop Newton openly maintained this doctrine. They divided dreams into two kinds,—good and evil,—and conceived that two kinds of agents, good and evil spirits, are concerned in their production: they consequently accounted for the one or the other sort of dreams, according as the one or the other kind of agents obtain a predominancy![3] It is not necessary to combat these views, —which ought of course to be as applicable to animals as to man,— especially as they are discarded. Dreaming is now properly considered to be an irregular action of the brain, in which the agency of the great controlling power of the will is suspended, and memory and imagination are allowed unlimited sway, so that the most singular and heterogeneous ideas are formed,—still kept, however, somewhat in train by the force of association. At times, indeed, this influence is so great, that every part of the dream appears to go on in the most natural and consistent manner. We witness scenes that have occurred during our waking hours; and seem to see, hear, walk, talk, and perform all the ordinary offices of life. The mind reasons, judges, wills, and experiences all the various emotions. Generally, the whole process is confined to the brain; but, at times, the muscles are thrown into action, and the expression of the feelings and emotions occurs as in the waking state. The dreamer moves, speaks, groans, cries, sings, &c., and if the dream concerns the generative function, the external organs respond, and emission takes place in the male to such an extent, occasionally, as

[1] Metamorphos., xi. v. 592 and 645.
[2] An Inquiry into the Nature of the Human Soul, &c., Lond., 1730.
[3] Good, op. cit., p. 194.

to constitute a true disease, or to be the cause of such,—the *paroniria salax* of Dr. Good,[1] *gonorrhœa dormientium* or *night pollution* of others. During the prevalence of a passion, too, the nutritive organs, in which its effects are experienced whilst awake, may be equally concerned during sleep. The respiration is short and interrupted; and sighs, groans, or laughter, according to the character of the emotion, are elicited; the heart beats with more or less violence; and this state of excitement continues after the individual has been completely aroused. *Nightmare*, *ephialtes* or *incubus* affords us an example of suffering as intense as could well be experienced during our waking moments. A sensation of distressing weight is felt at the epigastrium, and of impossibility of motion, speech, or even respiration; the dreamer fancies that some horrible form, or ferocious being is approaching him, and that all chance of escape is precluded; or that he is about to fall, or is falling, from a lofty precipice; and the anguish he suffers is indicated by loud groans, or by such painful feelings, apparently in the organs to which the emotions are referred, that he awakes. The ideas, at these times, are even more vivid than during the waking condition; the predominant perceptions not being detracted from by extraneous impressions. On many of these occasions, when we awake, the dream is fresh on the memory; and by resigning ourselves again to slumber, we can at times recall it, should it be of an agreeable character,—or dispel it altogether by rousing ourselves thoroughly.

On account of the greater vividness of the ideas during sleep, and their freedom from all distraction, intellectual operations are sometimes effected in a surprising manner;—difficulties being occasionally solved, which have obtained the mastery during waking. To a minor degree, every one must have experienced more or less of this. Composition, poetical or other, is often effected with great facility; and a clue is occasionally afforded, which leads to the solution of previous difficulties. Cardan had a notion, that he composed one of his works during sleep. Condillac, who attended greatly to this matter, remarked particularly, that, whilst engaged with his "*Cours d'Étude*," he frequently broke off a subject before retiring to rest, which he developed and finished the next morning according to his dreams. Condorcet saw in his dreams the final steps of a difficult calculation, which had puzzled him during the day; and Dr. Gregory, of Edinburgh, composed thoughts, and clothed them in words, which were so just in point of reasoning, and so good in point of language, that he used them in his lectures, and in his written lucubrations. Voltaire, Lafontaine, Franklin, Coleridge, and others, have made similar remarks; and events of the kind must have occurred, in some shape, to almost every one. Dr. Good relates a singular instance that happened to a friend of his, who, amongst other branches of science, had deeply cultivated music, of which he was passionately fond. He was a man of irritable temperament, ardent mind, and active and brilliant imagination; and "was hence," says Dr. Good, "prepared by nature for energetic and vivid ideas in his dreams." On one occasion, during sleep, he composed a beautiful little ode, of about six stanzas, and set the same to agreeable music, the im-

[1] Physiological System of Nosology, cl. iv. ord. 1, gen. v. sp. 3.

pression of which was so firmly fixed in his memory, that, on rising in the morning, he copied from his recollection both the music and the poetry.

In these cases, the will must direct, more or less, the intellectual process. It is scarcely conceivable, that the train of reasoning could go on so connectedly and effectively by association alone. That the will can, in some degree, be kept awake, or in a condition susceptible of being readily aroused, is shown by the facility with which we awake at a determined hour, and exercise a degree of watchfulness during sleep; as well as by the facts, previously mentioned, regarding the courier who sleeps on his horse, or the coachman on his box.

One curious fact, occasionally observed in dreams and likewise in the Mesmeric condition, which is analogous, in many respects, to what occurs in dreaming, is the calling up of impressions, that have been made at an antecedent period, and may have been entirely forgotten during the waking state. A well-known case of this kind is recorded in the books. A woman, during the delirium of fever, constantly repeated sentences unknown to her attendants, which proved to be Hebrew and Chaldaic. Of these she knew nothing whatever on her recovery; but on referring to her previous condition, it appeared, that she had formerly lived with a clergyman, who had been in the habit of reading aloud sentences in those languages; and these had impressed her mind without her knowledge.

Dr. Dewar relates the case of a girl, who, when awake, discovered no knowledge of astronomy, or other sciences; but when asleep could define the rotations of the seasons, using expressions the most apt to the subject; and Mr. Dendy[1] alludes to the case of an Edinburgh lady, who, "during her somnolent attacks, recited somewhat lengthy poems;" and it was curious, that each line commenced with the final letter of the preceding.

There is a kind of dreaming, in which the sleep is less profound than during ordinary dreams; and in which the body has, consequently, more capability of receiving external impressions, but the will has a certain degree of power over the muscles of voluntary motion, and imperfectly regulates the thoughts. This is *somnambulism* or *sleep-walking*. During the continuance of this state, the individual can apparently see, hear, walk, write, paint, speak, taste, smell, &c., and perform his usual avocations, yet remain, in other respects, so soundly asleep, that it is impossible to awake him without making use of violence. Cases are on record, and of an authentic nature, of individuals who have risen from bed asleep, with their eyes closed, and have not only walked about the room or house, going up or down stairs, finding their way readily and avoiding obstacles, but have passed with safety through very dangerous places, as windows, to reach the roofs of houses. They have executed, too, yet more difficult feats; such as dressing themselves; going out of doors; lighting a fire; bathing; saddling and bridling a horse; riding; composing verses, &c., and executing all the acts of life correctly, and even acutely; yet they were asleep during the whole

[1] The Philosophy of Mystery, p. 305, London, 1841.

time. The eyes have been shut, or, if open, have been incapable of perceiving the brightest light held before them; and the iris has not exhibited its irritability by contracting; so that it has been doubtful whether the ordinary functions of the eyes are generally executed during somnambulism; and the fact of the serious accidents, that occasionally befall the sleep-walker, is in favour of the negative. It must be remarked, however, that, in the opinion of some physiologists, the sight is awake and employed; and there are cases which strongly favour the idea. In these cases, the movements are regulated and co-ordinated; and if the cerebellum presides over this function—as is generally believed—it must be awake.

A peculiarity of ordinary somnambulism is, that the train of thoughts is usually directed towards one point, and this so profoundly, that notwithstanding the activity of the imagination, and the firm hold it takes on the mind, no recollection is retained of the occurrence during sleep, after the individual awakes either spontaneously or on being aroused.

Animal magnetism would seem to be capable of inducing a peculiar kind of somnambulism or *hypnotism*—as Mr. Braid[1] has termed it—in which new powers appear to be acquired, and intellectual operations executed of a most astonishing character. The records of the *Académie Royale de Médecine*, of Paris, contain many such instances. A singular case of somnambulism is recorded by Dr. Belden, of Springfield, Vermont.[2] It occurred in a young female, 17 years of age; and the phenomena were attested by numerous observers. One striking circumstance in the case was the astonishingly developed impressibility of the eye. As an evidence of this, when Dr. Belden, in order to test the sensibility of the organ, took, one evening, a small concave mirror, and held it so that the rays proceeding from a lamp were reflected upon her closed eyelid, and the light was so diffused, that the outline of the illuminated space could scarcely be distinguished, the moment it fell on the eyelid, it caused a shock equal to that produced by an electric battery. This female could see as well, apparently, when the eyes were closed as when they were open. The details of the case—and indeed of every case—of somnambulism are full of interest to the mental philosopher.

Of late years, the various experiments, at one time so much in vogue, when mesmerism was in fashion—have been repeated not only by those who are not in the ranks of the profession, but by some estimable physicians; and of the reality of certain of the effects ascribed to the manipulations of the animal magnetizer no doubt can be entertained. The whole history of the art exhibits, that impressible individuals may have irregularities of nervous distribution induced through the medium of the senses, especially through those of vision and touch,—and that somnambulism and hysteric sleep, with other phenomena referable to a like condition of the nervous system, may be engendered; but that there is any thing like a magnetic fluid or agent, which may be communicated from the magnetizer to the subject of his experiments, is

[1] Neurypnology, or the Rationale of Nervous Sleep, considered in Relation with Nervous Magnetism; and Edinburgh Medical and Surgical Journal, Oct., 1846; copied into Amer. Journal of the Medical Sciences, Jan., 1847, p. 231.

[2] American Journal of the Medical Sciences, No. xxviii.

not only not proved, but in the author's opinion, by no means presumable. Mr. Braid,[1] indeed, affirms, that the most effectual of all modes of inducing somnambulism is for the subject himself to take any bright object—Mr. Braid generally uses his lancet-case—between the thumb and fore and middle fingers of the left hand; hold it from about eight to fifteen inches from the eyes, at such a position above the forehead as may be necessary to produce the greatest possible strain upon the eyes and eyelids; and enable the subject to maintain a steady fixed stare at the object. After a time, in a proper individual, the phenomena will present themselves. Some years ago, the author knew a highly *hypnotizable* gentleman, who could speedily induce the phenomena on himself by looking at a pointed metallic body—the point of his penknife for example.

A most curious phenomenon presented by this singular condition is the greatly developed sensibility to some irritants, and the total insensibility to others. Thus, the author has seen different persons bear, without the slightest muscular contraction, the application of a straw or feather to the conjunctiva; the insertion of pointed bodies into various parts of the cutaneous surface; the extraction of a tooth, &c., and yet start at the least puff of air on the face. From what he has himself seen, he can readily credit the statements affirmed on respectable testimony, that even the major operations of surgery may have been executed, whilst the patient was in this state of *mesmeric sleep*—if it may be so termed. As to the Hellsehen, *clairvoyance*, or "lucidity of vision," said to have been possessed by the magnetized, could he assign his belief to it at all, it would be only on the ground—"*credo quia impossibile est.*"

One of the most startling of modern announcements was, that if a compartment of the skull, mapped out by the phrenologists, be touched, whilst a person is in the mesmeric state, he will immediately have his thoughts turned in the direction of the mental faculty that corresponds with the particular phrenological organ, and exhibit manifestations thereof in his actions and speech. Some of the phenomena witnessed by the author have certainly been most strange; and at first sight were strongly confirmatory of a union between phrenology and magnetism or "*phreno-magnetism*," and, therefore, of the truth of both. It has been sufficiently demonstrated, however, that where the person operated upon has had no previous acquaintance of any kind with phrenology, not the slightest manifestation can be elicited; and that by stating aloud, that the manipulator is about to touch a certain organ, whilst, in reality, he touches another, the thoughts and actions have been immediately made to correspond with the organ mentioned,—not with the one over which the finger was placed.[2]

The causes of imperfect or incomplete sleep, and hence of dreams, are various. The fact, already referred to, of the different organs of

[1] Op. cit., and Carpenter, art. Sleep, Cyclop. of Anat. and Physiology, Pt. xxxv. p. 695, March, 1849.

[2] See, on the subject of Somnambulism, Carpenter, Art. Sleep, in Cyclop. of Anat. and Physiology, iv. 691, London, 1852; and on mesmerism, table-talking, table-turning, and various manifestations of expectant attention, the same loc. cit. in London Quarterly Review, Oct., 1853, and in Principles of Human Physiology, Amer. edit., Philad., 1855.

the animal functions having their distinct periods of waking and rest, would induce us to suppose, that it ought not to be always equally profound and durable; yet there are persons whose sleep is nearly complete throughout. The previous occupation of the sleeper exerts great influence. If it has been of a fatiguing nature, all the faculties rest equally long and soundly; but if the fatigue extends beyond the due point, a degree of excitability of the brain is left which renders it extremely liable to be aroused. In this way we understand why dreams should bear upon subjects that have long occupied the mind in its waking state—the tension of the mind on those subjects having left greater excitability, as respects them, and a disposition to resume them under the slightest irritation. The presence or absençe of irritants—external or internal—exerts likewise a great effect on the soundness of sleep, and the formation of dreams. The stillness of night and absence of light are hence favourable to repose; the position, too, must be one devoid of constraint; and the couch soft and equable, and especially such as the individual has been accustomed to. Sleep is impracticable in a badly made bed; and every one must have experienced the antisoporific influence of a strange couch, the arrangement of which, as to size, pillows, &c., differs from that to which he has been habituated. It is not, however, by external irritants that sleep is usually disturbed. The state of the system itself may react upon the brain and give occasion to broken sleep, and to dreams of a most turbulent character. Irritations existing in the viscera are frequently the cause of dreams,—in children more especially; and a hearty supper, particularly if of materials difficult of digestion, may bring on the whole train of symptoms that characterize nightmare. In like manner, any thing that impedes the action of the functions of respiration, circulation, &c., may occasion the wildest phantasies. All these internal impressions are more vividly perceived for the reasons already stated. The nervous system is no longer excited by the ordinary impressions from the external senses; and if the internal impressions be insufficient to prevent sleep altogether, they may excite dreams.

During this incomplete kind of sleep, the external sensations are not wholly at rest; particularly that of touch or tact, which, as it is the last to sleep, is the first to awake. Impressions made on it may excite the most exaggerated representations in the brain, in the shape of dreams. The bite of a flea appeared to Des Cartes the puncture of a sword: an uneasy position of the neck may excite the idea of strangulation: a loaded stomach may cause the sleeper to feel as if a heavy weight,—a house or castle, or some powerful monster,—were on his stomach. A person, having had a blister applied to his head, dreamed that he was scalped by a party of Indians. Moreau de la Sarthe gives the case of a young female, who, from the application of her cold hand against her breast, when asleep, dreamed that a robber had entered her apartment, and had seized hold of her. Galen dreamed that he had a stone leg, and, on waking, found that his own was struck with paralysis. Mr. Dugald Stewart[1] gives a similar case, to show how an impression made upon the body, during sleep, may call up a train of

[1] Elements of the Philosophy of the Human Mind, i. 335, 3d edit., Lond., 1808.

associated ideas, and thus produce a dream. A gentleman, (Dr. Gregory,) who, during his travels, had ascended a volcano, having occasion, in consequence of indisposition, to apply a bottle of hot water to his feet when he went to bed, dreamed that he was making a journey to the top of Mount Ætna, and that he found the heat of the ground almost insupportable. Sir Walter Scott[1] mentions an analogous instance, which was told him by the nobleman concerned. He had fallen asleep, with some uneasy feelings arising from indigestion, which brought on the usual train of visionary terrors. At length, they were all summed up in the apprehension, that the phantom of a dead man held the sleeper by the wrist, and endeavoured to drag him out of bed. He awoke in horror, and still felt the cold dead grasp of a corpse's hand on his wrist. It was a minute before he discovered, that his own left hand was in a state of numbness, and that he had accidentally encircled his right arm with it. On another occasion, Dr. Gregory dreamed of spending a winter at Hudson's Bay, and of suffering much distress from the intense frost—the dream being evidently the consequence of his having thrown off the bedclothes in his sleep, added to his having been reading, a few days before, a very particular account of the state of the colonies in that country during winter. Dr. Reid, having a badly dressed blister on his head, dreamed that Indians were scalping him; and a man in a damp bed dreamed that he was being dragged through a stream.[2] If, again, the organ of hearing be wakeful, the dreamer may hear a person speak to him, and reply; so that occasionally secret thoughts and feelings may be elicited. The author has himself answered several times connectedly in this manner; and has been able to lead others, especially children,—whose sleep is often interrupted by the existence of irregular internal impressions,—to respond a few times in the same way.

It would seem, that on the loss of any one sense, the dreams, after a lapse of time, cease to refer to it. Dr. Darwin has given many instances of this. After blindness had long affected certain persons, they never dreamed that they saw objects in their sleep; and a deaf gentleman, who had talked with his fingers for thirty years, invariably dreamed of finger-speaking; and never alluded to his having dreamed of friends having conversed orally with him.

In the explanation of the cause of dreaming, we have the most plausible application of the theory of Gall regarding the plurality of cerebral organs. Every explanation, indeed, takes for granted, that certain faculties are suspended whilst others are active. Gall's view[3] is, that, during sleep, particular organs of animal life enter into activity; and hence, that the perceptions and ideas, which depend on these organs, awake; but, in such case, their activity takes place without any influence of the will;—that when one organ only is in activity, the dream is simple: the dreamer caresses the object of his affection; he hears melodious music, or fights his enemies, according as this or that organ is exercising its functions;—that the greater the number of

[1] Letters on Demonology and Witchcraft, Amer. edit., p. 49, New York, 1830.
[2] Carpenter, Art. Sleep, op. cit., p. 688.
[3] Sur les Fonctions du Cerveau, ii. 506, Paris, 1825.

organs in activity at the same time, the more confused or complicated will be the dream, and the greater the number of extravagancies;—that, when the organs are exhausted by watching and labour, we generally do not dream during the first hours of sleep, unless the brain is extremely irritable; but, in proportion as the organs get rid of their fatigue, they are more disposed to enter into activity, and hence, near the time for waking, we dream more, and with greater vivacity. "Dreaming, consequently," he concludes, "is only a state of partial waking of animal life; or, in other words, an involuntary activity of certain organs, whilst others are resting."

In many respects, the state of the mind during dreaming resembles that in the delirium of fever, as well as in insanity. The imagination and memory may be acting with unusual vivacity, whilst the perception or the judgment may be erroneous;—at times, the perception being accurate and the judgment suspended, so that the individual may be most incoherent; at others, the perception being inaccurate and the judgment right, so that he may reason correctly from false premises. As in dreams, too, the delirious may have their ravings modified by impressions made on the external senses. Sir Walter Scott[1] cites the case of a lunatic confined in the Infirmary of Edinburgh, whose malady had assumed a gay turn. The house, in his idea, was his own, and he contrived to account for all that seemed inconsistent with his imaginary right of property. There were many patients in it, but that was owing to the benevolence of his nature, which made him love to relieve distress. He went little, or rather never, abroad,—but then his habits were of a domestic and rather sedentary nature. He did not see much company, but he daily received visits from the first characters in the celebrated medical school of the city; and he could not, therefore, be much in want of society. With so many supposed comforts around him, with so many visions of wealth and splendour, one thing alone disturbed his peace. "He was curious," he said, "in his table; choice in his selection of cooks; had every day a dinner of three regular courses and a dessert, and yet somehow or other, everything he ate tasted of porridge." The cause of this was, that the lunatic actually ate nothing but porridge at any of his meals; and the impression made upon his palate was so strong as to modify his delusion.

2. WAKING DREAMS.

Nearly allied to dreams, in its physiology, or—more properly, perhaps—pathology, is the subject of *hallucinations*, *spectral illusions*, or *waking dreams*, in which the mind may be completely sound, and yet the part of the brain concerned in perception be so deranged as to call up a series of perceptions of objects, that have no existence except in the imagination. Such hallucinations are constant concomitants of insanity, delirium, and dreaming; but they may occur, also, when the person is wide awake, and in the full possession of his reasoning powers: he may see the phantasm, but at the same time totally disbelieve in its existence. The most common illusions of this kind affect the senses of sight and hearing.

[1] Op. citat., p. 26.

It has fallen to the lot of the author to meet with singular and serious cases of this affection; where, for example, the person wide awake, has heard the doors of his house violently slammed; his windows thrown up and down; the bells set a ringing; himself subjected to personal violence; yet there has been no slamming of doors, no throwing up and down of windows; no ringing of bells; no personal violence: the whole has been an illusion, a waking dream, and of this no one has been more entirely aware than the sufferer himself. A few years ago, the author was consulted by a most respectable citizen of Virginia, regarding his state of health as well as an illusion of this nature. He was one of the Board of Visitors at West Point, where his duty required him to inspect the demonstrations of the pupils on the black-board. For months after his return to Virginia, he saw the black-board with its demonstrations constantly before him. He had previously experienced an attack of paralysis, and, when he applied to the author, was labouring under marked evidences of predisposition to a farther access of encephalic mischief, of which the illusion in question was doubtless one. A most impressive case of the kind is that of Nicolai, the eminent bookseller of Berlin, which has been detailed by Drs. Ferriar[1] and Hibbert,[2] and by Dr. Haslam[3] and Mr. Mayo.[4] Nicolai laid his case before the Philosophical Society of Berlin. He traced his indisposition,—for it was manifestly such,—to a series of disagreeable incidents that had befallen him. The depression, thus induced, was aided by the consequences of neglecting a course of periodical bleeding to which he had been accustomed. This state of health brought on a disposition to spectral illusions; and, for a time, he was regularly haunted by crowds of persons entering his apartment, and addressing him or occupied solely in their own pursuits; until, as his health was restored, they gradually disappeared, and ultimately left him entirely. Yet Nicolai, who was a man of unusually strong intellect, was satisfied throughout, that they were mere hallucinations.

The cases of the kind, now on record, are many and curious. Every one engaged in extensive practice, or in frequent communion with the world, must have seen or heard of them. Some, of a deeply interesting character, are detailed by Sir David Brewster,[5] Dr. Abercrombie,[6] and Dr. Macnish;[7] but there are none more extraordinary than those that have been related by Sir Walter Scott.[8] They are signal examples of the illusions that may occur during even our waking moments; and may, doubtless, account for some of the stories of apparitions, of which so many are on record. In the hypochondriac, we meet with all kinds of hallucination, and it is one of the most striking of the

[1] An Essay towards a Theory of Apparitions, Lond., 1813.

[2] Sketches of the Philosophy of Apparitions, Edinb., 1825.

[3] Medical Jurisprudence as it relates to Insanity, in Cooper's Tracts on Medical Jurisprudence, p. 302, Philad., 1819.

[4] Outlines of Human Physiology, 3d edit., p. 213, Lond., 1833.

[5] Letters on Natural Magic, Amer. edit., p. 42, New York, 1832.

[6] Inquiries concerning the Intellectual Powers and the Investigation of Truth, Amer. edit., p. 282, New York, 1832.

[7] Philosophy of Sleep, Amer. edit., p. 214, New York, 1834.

[8] Letters on Den onology, &c., Amer. edit., p. 34, New York, 1830.

symptoms of every variety of insanity; but, in the cases referred to, notwithstanding the constancy and permanency of the illusion, the individual himself has been satisfied, that the whole affair had no real existence. Had he believed in the existence of the phantom, and acted from a conviction of its reality, he might, with propriety, have been deemed insane *quoad hoc*. An instance of this kind is told in the Memoirs of the Count Maurepas of one of the princes of the House of Bourbon, who supposed himself a plant; and having fixed himself in the garden, called upon his servant to come and water him. His belief argued unsoundness of mind; yet the hallucination, we are told, appeared to be confined to this subject. Usually, these spectral illusions persist, until the morbid cause producing them is removed. All, indeed, that have fallen under the author's notice, have been of this character. No matter where the individual may be, the phantom is present. It is affirmed, however, in a recent medical periodical,[1] that a gentleman of Boston, known for his intelligence and enterprise, has had for years past a hallucination, whenever he enters a certain gate in front of a relative's house. He is met by a large, full-faced, florid-complexioned man, dressed in a broad-brimmed white hat. This occurs at all hours of the day. The spectre recedes from him as he advances; and, near the house, is lost in air. The gentleman assured the editor of the journal, that he takes pleasure in looking his intangible visitor full in the eye; examines the colour and fashion of his garments; and now regards him as an old and familiar acquaintance. In this case, the hallucination is evidently called up by morbid associations connected with the particular impression made on the brain by local objects through the sense of sight; and does not exist except when such objects are present. In youth, when imagination is extremely vivid, we can call up images in the mind at pleasure, varying them as we may think proper. In the nervous, the delicate, and the imaginative, uneasy sensations may be felt when and where the individual wishes. After long continued sedentary habits, the author has been able to experience, at will, pain in any part of the system, and to make it shift at pleasure from one organ to another.

In the cases of hallucination, referred to above, as well as in every other kind, the cerebral part of the organ of sense is directly or indirectly excited into action;—often by disease of the brain, or of some distant organ which reacts upon it. Hence it occurs as a precursor of apoplexy, epilepsy or other cerebral affection; or it may accompany, or be aggravated by, disorder of the digestive function. It has been seen, that although the passions or emotions are cerebral phenomena, they are felt in the nutritive organs; and we can understand how a disordered state of those organs may react upon the brain, and call up all kinds of illusions;—generally during sleep, but at times even during our waking moments. In this way, we account for the frightful dreams that follow an overloaded stomach, or accompany impeded respiration or circulation. One of the most distressing symptoms of hydrothorax or water in the chest, a disease that interferes more or less with both these vital functions, is the disturbed sleep, and frightful

[1] Boston Medical and Surgical Journal, 1846.

sense of impending danger, which nightly distress the unfortunate sufferer.

It appears, then, that in all cases of hallucination, occurring in those of sound or diseased mind, asleep or awake, the encephalic or percipient part of the organ of the sense concerned is irresistibly affected, so as to call up the memory of objects, or to form others that have no existence except in the imagination; but all this is accomplished without any impression being made upon the external senses from without, even when these senses appear to be most actively exercised. In dreams, this must manifestly be the case. We see a friend long since dead: we parade the streets of a town we have never visited; and see, hear, feel, and touch the different objects. All this must be encephalic; and not less certainly is it the case in the hallucinations of insanity, or in those that occur in the waking condition. The object we see is not in existence, yet it is a regularly defined creation; a cat in one instance, a gentleman usher in another, and a skeleton in a third. It cannot depend upon any depraved condition of the organ of sense, as in such case the representation of the mind would be amorphous, irregular, or confused; not a complete metamorphosis, as is invariably the case. Yet Sir Walter Scott[1] states, that he thinks "there can be little doubt of the proposition, that the external organs may, from various causes, become so much deranged as to make false representations to the mind; and that in such cases, men, in the literal sense, really *see* the empty and false form, and *hear* the ideal sounds, which, in a more primitive state of society, are naturally enough referred to the action of demons or disembodied spirits. In such unhappy cases, the patient is intellectually in the condition of a general, whose spies have been bribed by the enemy, and who must engage himself in the difficult and delicate task of examining and correcting, by his own powers of argument, the probability of the reports, which are too inconsistent to be trusted to." The explanation is poetic, but manifestly untenable.

A theory, which has been offered to account for the various spectral illusions occurring in any of the modes mentioned, is—that in all the organs of sense, the mind possesses the power of retransmitting, through the nervous filaments, to the expansions of the nerves that are acted upon by external objects, impressions, which these nerves have previously transmitted to the brain, and, that the vividness of the retransmission is proportional to the frequency with which the impressions have been previously transmitted; that these reproduced impressions are in general feeble in the healthy state of the body, though perfectly adapted to the purposes for which they are required; but, in other states of the body, they appear with such brilliancy as to create even a belief in the external existence of those objects from which the impressions were originally derived. "When the mind," says a writer on this subject, "acquires a knowledge of visible objects it is by means of luminous impressions conveyed to the sensorium from each impressed point of the retina through the corresponding filaments of the optic nerve; and when the memory is subsequently called upon, by an act of the will, to present to us an object that has been previously seen,

[1] Op. cit., p. 40.

it does it by retransmission along the same nervous filaments, to the same points of the retina. In the first case, when the presence of the luminous object keeps up a sustained impression upon the nervous membrane, the filaments, which transmit it to the brain, are powerfully excited; but, in the process of retransmission by an effort of memory, the action of the nervous filaments is comparatively feeble, and the resultant impression on the retina faint or transient. When the memory, however, is powerful, and when the nervous filaments are in a state of high excitability, the impression becomes more vivid; and, as in the case of spectral illusions, it has the same strength and distinctness, as if it were produced by the direct action of luminous rays. In one case, the result of the impression and its retransmission to the retina is a voluntary act of the mind, but, in the other, it is involuntary, the controlling power being modified or removed, or the nerves being thrown into a state of easy excitation by some unhealthy action of the bodily organs."

According to this view, it is indispensable, that perception, in every case of illusion, shall be referred to the nerves of the organ by which such perception is ordinarily effected; to the retina, if vision; to the auditory nerve, if audition be concerned; and so on. But this retransmission along the nerves would appear to be wholly unnecessary. When an impression is made upon a sensitive surface, as we have elsewhere shown, sensation is not accomplished until the impression has been conveyed to the brain, and the brain has acted; and if we interfere in any manner with the cerebral part of the function, perception is not effected. From the moment, however, that the action of the brain has taken place, the idea formed can be recalled by the exercise of memory; and we have no doubt that this could take place for a time, although the eyes were extirpated. The memory may call up previous perceptions, when the functions of the retina are entirely destroyed. In dreams we exert every one of the senses; some with the greatest activity. We see, hear, taste, smell, and feel; and, in addition to this, seem to walk, run, fly, and execute the ordinary acts of life, not only without apparent difficulty, but with a facility that surprises us. Yet can we suppose, that in all these cases, feeling is actually produced by retransmission along the nerves of the organ to which it is referred? It has been asserted, that when examination is carefully made it will be found, that the images recalled by the memory, follow the motions of the head and eye; but, that this is not the case during sleep is manifest. The individual may remain in the same position, and yet seem to move about in all directions in his dreams; appear to see objects behind as well as before him; and in situations towards which it is impossible that the motions of his head and eye should be directed. Even in most of the illusions of our waking hours the remark ought to be reversed. The encephalic action is the first of the links in the chain of phenomena; and the motions of the head and eye follow the images recalled by the memory. When the unfortunate subject of one of the cases of hallucination recorded by Sir Walter Scott saw the gentleman-usher preceding him into company, and circulating among the assembled guests —as well as when he observed the skeleton at the foot of his bed—the

perception, owing to disease, had so completely taken possession of a part of the encephalic organ of vision, that the idea was constantly in the mind; and volition being actively exercised, the head and eye were directed towards the phantasm. Yet the perception was not so powerful as to preclude the reception of impressions from without, as was shown by the skeleton seeming to be shut off by the body of the physician, so that the skull only was seen peering above his shoulder.

Another fact, which shows, that the whole phenomenon may be entirely encephalic, is the occurrence, familiar to the operative surgeon, of a patient, whose lower limb has been amputated, complaining of an uneasy sensation, as of itching, in a particular toe, and in a particular part of a toe. This is, at times, a symptom of an extremely distressing character. It is obviously impossible, that in such a case there can be any external impression made on the part to which the feeling is referred; or that any retransmission can occur from the brain—the limb having been removed from the body. M. Broussais asserts, that if a person tells you he suffers in a limb which he no longer has, it is because he experiences irritation in the extremities of the divided nerve; but this, in no respect, removes the difficulty. The sensation is referred to a part, which has no existence except in the imagination.

But, to return to sleep. We have said, that the object of sleep is to repair the loss sustained by the nervous system, during the previous condition of waking. This may, consequently, be regarded as the great exciting cause of sleep; but we have seen, also, that certain states of the mind may postpone the usual period of its recurrence. If, indeed, we allow the attention to flag, and suspend the due exercise of volition, sleep can be indulged at almost any hour of the day. In the same manner, any monotonous impression, or action of the brain in thought; the rocking of a cradle, or the song of the nurse to a restless child; the murmurs of a bubbling brook, &c., may soothe to rest. A like effect is produced by substances, as narcotics, which, by a specific action on the nervous system, prevent the ordinary sources of irritation from being appreciated, as well as by certain morbid affections of the brain—compression, concussion, inflammation, &c. In these cases, however, the sleep is morbid, and an evidence of serious mischief—often of fatal disease; whilst true sleep is as natural as the waking state, and is always—

> "Man's rich restorative; his balmy bath,
> That supples, lubricates, and keeps in play
> The various movements of that nice machine,
> Which asks such frequent periods of repair."
>
> Young's *Night Thoughts.*

Yet Haller,[1] Hartley,[2] and numerous others have supposed, that natural sleep is dependent upon an accumulation of blood or other fluids in the vessels of the head pressing upon the brain, and thus impeding its functions. In support of this opinion, it is asserted, that all the phenomena which attend the sleeping state seem to prove a

[1] Element. Physiolog., xvii. 3. [2] On Man, p. 45, Lond., 1791.

determination of blood to the head. The face is flushed; the head hotter; the skin more moist; and it is generally during the night, or when first awake, that bleeding from the nose and apoplexy take place; the frequency of erection during sleeping is affirmed to be owing to the pressure exerted on the cerebellum, which, in the theory of Gall, is the encephalic organ of generation; and, lastly, it is argued, that narcotics, and vinous and spirituous liquors produce sleep by causing a similar congestion of blood within the cranium. The case, by no means unique, of the beggar whose brain was exposed, and in whom a state of drowsiness was induced when it was pressed upon, which could be increased by increasing the pressure, until at length he became comatose,—has also been cited by Hartley and others. But most of these are cases of morbid suspension of the animal functions, and are no more to be likened to true sleep, than the drowsiness, which M. Flourens[1] found to prevail in his experiments on animals when the cerebral lobes were removed.

The believers in the hypothesis, that congestion of the vessels of the brain is the cause of sleep, consider that the heaviness and stupor, observable in those who indulge too much in laziness and sleep, are owing to long-continued pressure injuring the cerebral organs. Other physiologists have assumed the opposite ground, and affirmed, that during sleep the blood is distributed to the brain in less quantity, and is concentrated in the abdomen, to augment the action of the nutritive functions; whilst M. Cabanis[2] holds, that during sleep there is a reflux of the nervous powers towards their source, and a concentration in the brain of the most active principles of sensibility. On all these topics our ignorance is extreme. We know nothing of the state of the encephalon in sleep. Its essence is as impenetrable as that of every other vital function. Dr. Bostock[3] asserts, that it is not more beyond our grasp than other functions of the nervous system. This we admit: he has, indeed, afforded in his own work indubitable evidences of our utter want of acquaintance with the essence of all those functions. That there is, during sleep, a modified condition of the encephalic neurine can admit of no question; but in what that modification consists we may express our entire ignorance. Cases are recorded[4] in which, in a healthy condition of the system in other respects, sleep has been protracted almost continuously for days or even weeks. These, Dr. Carpenter[5] does not regard as examples of natural sleep; "the state of such persons being more closely allied to hysteric coma." They are singular cases; and their essence is involved in the obscurity that involves the whole subject.

The state of sleep is as natural, as instinctive, as that of waking; both are involved in mystery; and their investigation, as Mr. Dugald

[1] Expériences sur le Système Nerveux, Paris, 1825.

[2] Rapport du Physique et du Moral de l'Homme, Paris, 1802.

[3] Elementary System of Physiology, 3d edit., p. 815, Lond., 1836.

[4] See the case of Samuel Chilton in Philosph. Transactions for 1694; and that of Mary Lyall in Transactions of the Royal Society of Edinburgh for 1818. A similar case has been recently recorded in the public journals of this country.

[5] Art. Sleep, in Cyclop. of Anat. and Physiol., iv. 687, Lond., 1852; and Principles of Human Physiology, Amer. edit., p. 616, Philad., 1855.

Stewart[1] has suggested, is probably beyond the reach of the human faculties.

3. REVERY.

Revery has been considered to resemble sleep, and, in its higher grades, to be not far removed from the condition of somnambulism. It is characterized by the attention or volition being directed so intently towards particular topics, during wakefulness, that the impressions of surrounding objects are not appreciated. Various grades of this condition of the mind may be traced, from the slightest degree of *absence* or *brown study* to a state in which the attention is entirely wound up, and riveted on a particular subject. Most persons must have experienced more or less of this, when any subject of severe study, or any great gratification, anxiety, or distress has strongly occupied the mind. If engaged in reading, they may follow every line with the eye; turn over leaf after leaf; and at length awake from the revery, which had occupied the imagination, and find that not the slightest impression had been made on the mind by the pages, which the eye had perused, and the hand had passed over. If walking in a crowded street, they may have proceeded some way under the influence of revery, moving the limbs as usual, performing various acts of volition, winding safely among the passengers, avoiding the posts and other obstacles, yet so exclusively occupied by the conceptions of the mind, as to be totally unconscious of all these acts of their volition, and of the objects they have passed, which must necessarily have impressed their senses so as to regulate those actions; but, owing to the attention having been bent upon other topics, the perceptions were evanescent. In elucidation of the power of a high degree of revery to render an individual torpid to all around him, the case of Archimedes, at the time of his arrest, has been quoted by writers. When the Roman army had at length taken Syracuse by stratagem, which the tactics of Archimedes had prevented them from taking by force, he was shut up in his closet, and so intent on a geometrical demonstration, that he was equally insensible to the shouts of the victors, and the outcries of the vanquished. He was calmly tracing the lines of a diagram, when a soldier abruptly entered his room, and clapped a sword to his throat. "Hold, friend," says Archimedes, "one moment, and my demonstration will be finished." The soldier, surprised at his unconcern at a time of such extreme peril, resolved to carry him before Marcellus; but as the philosopher put under his arm a small box-full of spheres, dials, and other instruments, the soldier, conceiving the box to be filled with gold, could not resist the temptation, and killed him on the spot.[2]

It is to the capability of indulging to the necessary extent in this kind of mental abstraction, that we are indebted for the solution of every abstruse problem relating to science or art, and for some of the most beautiful conceptions of the poet. From indulgence, however, in such abstractions, a habit is often acquired, which may be carried so far as to render the individual unfit for society, and give him a cha-

[1] Elements of the Philosophy of the Human Mind, i. 327, 3d edit., Lond., 1808.

[2] Liv. l. xxxv., c. 3, and Good, Study of Medicine, Amer. edit., iii. 312, Philad., 1824.

racter for rudeness and ill-breeding, of which he may be by no means deserving. Some most amiable and estimable men have, from long habits of abstraction, contracted the *disease* (*aphelxia*), as Dr. Good[1] has constituted it, and have found the cure tedious and almost impracticable; at times, indeed, it appears to have terminated in mental alienation. The difference between this state and that of sleep is, that the attention and volition are here powerfully directed to one object, so as to be torpid to the impressions of extraneous bodies; whilst sleep is characterized by a suspension or irregular exercise of these faculties.

CHAPTER III.

CORRELATION OF FUNCTIONS.

THE wonderful and complicated actions of the frame are variously correlated to accomplish that astonishing harmony, which prevails in the state of health, as well as to produce the varied morbid phenomena,—often at a distance from the part originally diseased,—which characterize different pathological conditions. It is not, therefore, simply as a physiological question, that the study of the correlation of functions interests the medical inquirer. It is important to him in the study of every department, which concerns the doctrine of the healthy or diseased manifestations, and the modes adapted for the removal of the latter. The correlations may be of various kinds;—*mechanical*, in which the effect exerted is entirely of a mechanical character; *functional*, in which the action of one organ is inseparably united to that of another, to accomplish a particular object; and *sympathetic*, in which there is no physical action or direct catenation of functions, but where an organ at a distance from one affected is excited to regular or irregular action in consequence of the condition of the latter.

1. MECHANICAL CORRELATIONS.

In the description of the different functions, numerous opportunities occurred for showing the influence which organs, in the immediate vicinity of each other, may mutually exert so as to modify their functions. The action of the muscles,—particularly those that contract the larger cavities, as the abdomen and thorax,—on the parts with which they come in contact, must be entirely mechanical. In this way, the diaphragm and abdominal muscles act in vomiting and defecation. During the operation of blood-letting, the flow of blood can be augmented by moving the muscles of the hand; and it is probable, that the constant motion of the muscles of respiration impresses a succussion on different organs, which may aid them in accomplishing their functions, although the effect of this is doubtless exaggerated. Every change of position, either of the whole body or of a part, has likewise some effect in modifying the actions performed by it or by neighbouring organs, although such effect may not be easily appreciable. A similar case of mere mechanical influence, which seems to be

[1] A Physiological System of Nosology, cl. iv., ord. 1, gen. v.

important to the proper action of certain organs, is exhibited in the pulsation of the different arteries. It has been seen, that a succussion is in this way given to the brain, which appears to be necessary to it; for if this source of stimulation be in any manner withdrawn fainting is induced. Perhaps, however, the strongest case that can be offered of modification of function by mechanical causes, is that of the gravid uterus, which, by its pressure, gives rise to numerous symptoms in other organs, that are often the source of annoyance during gestation.

2. FUNCTIONAL CORRELATIONS.

The *functional correlations* or *synergies* are of much more moment to the physiologist and pathologist. Many of these have also been described in the preceding history: a brief notice of them will be all that is now requisite. For the maintenance of the healthy function we know that certain conditions are necessary, and that if these be materially modified, in the whole or in any part of the body, disease and death may be the result, even although the derangement may, in the first instance, concern only an apparently unimportant part of the frame,—the affection, by correlation, spreading gradually to more and more essential organs and functions, until the disorder is ultimately too great to allow of a continuance of the vital movements. In this respect, man differs from an ordinary piece of mechanism, in which the various parts are so adapted to each other as to produce a certain result. If one of these parts be destroyed, the whole machine may have its motion arrested; but the effect is owing to the destruction of one part only, the others remaining sound; whilst death, or the stoppage of the living machine, does not necessarily follow the destruction of any except a few essential organs, and is generally owing to the derangement of many. We shall find, indeed, that except in cases of sudden death, it is extremely difficult to say which of the three truly vital organs has first ceased to act; and that in all such cases death begins in one or other of the organs essential to vitality, and soon extends to the rest.

The essentially vital organs are those of respiration, circulation, and innervation; but the great use of respiration is to change the blood from venous to arterial; in other words, to induce a conversion in it by its passage through the lungs, without which it would be inadequate for the maintenance of life in any organ; and the object of the circulation is, to distribute it to the various parts of the frame as the grand vivifying and reparatory material. If, also, the organs of innervation be destroyed, the nervous influence is no longer conveyed to the different parts of the frame; and as the presence of this influence is indispensable, the functions may cease from this cause; so that we may regard as essential elements to the existence of the frame and of every part of it a proper supply of arterial blood and nervous influence. In the production and distribution, however, of these agencies, a number of functions is concerned, giving rise to the correlation, which is the object of the present inquiry. If, in any manner, the blood does not meet with due aeration, as in ordinary cases of suffocation, death supervenes in the order elsewhere described; and if a slight degree of aeration is accomplished, but still not enough for the necessities of the system, instead

of suffocation, the individual dies more gradually; the functions fail in the same order; dark blood circulates through all the textures; hence lividity, especially of those parts where the cuticle is extremely thin, as of the lips, and wherever the mucous membranes commingle with the skin; the blood gradually becomes inadequate to keep up the action of the brain and nervous system generally, as well as to stimulate the heart, and the individual gradually expires. If, again, the blood, although properly converted in the lungs, be not duly distributed to the organs, owing to the failure of the circulatory powers,—either from direct or indirect causes,—the organs exhibit their correlation in the same manner, and syncope or fainting, or positive death, may be induced. Often, however, the stoppage of the action of the heart is but for a short time. Owing to some painful impression, sudden emotion, or other cause, the organ ceases to contract, either suddenly,—when the person falls down as if deprived of life,—or gradually, when the connection of the different functions, and the order in which they fail, are manifest. Of this kind of—what the surgeon calls—*morbid sympathy* or *constitutional irritation*, we have a good example in the effect of a trifling operation on a delicate, and often on a strong, individual. Bleeding induces fainting,—both directly, by the abstraction of fluid from the vessels, so that the brain may cease to act; and indirectly, when the quantity removed cannot be presumed to have exerted any influence. Some, indeed, faint from the slightest puncture and loss of blood, or even from the sight of that fluid. In these last cases, if the syncope comes on gradually, a feeling of anxiety and oppression, occasionally of vacuity, exists in the epigastric region, perceptions become confused; the sight is obscured; tinnitus aurium and dizziness supervene; the respiration is embarrassed; the face pale; the extremities are cold, and the different parts of the body covered with a cold, clammy sweat, until, ultimately, loss of sensation and motion supervenes, and the individual is temporarily dead; from which state he soon recovers, in the generality of cases, provided he is kept in the recumbent posture, so that the blood may readily pass to the brain.

On other occasions, the heart does not cease its pulsations, but continues to send blood, in undue quantity, to the brain, so that all the above phenomena may ensue, except the temporary privation of vitality. In consequence of the severe pain induced by a displacement of two of the bones of the wrist, by a fall from a carriage, the author remained a considerable time incapable of sight, and at the same time suffering from great anxiety and oppression; yet consciousness and the action of the heart never ceased as in complete syncope. The third vital function,—that of innervation,—when suspended or diminished, draws on a train of morbid phenomena in the order described under the head of Death; arresting respiration and circulation suddenly, if the cause applied be sufficient; more gradually, and with symptoms characterizing apoplexy or compression of the brain, if the cause acts in a minor degree. All the three vital functions are consequently correlative, and so intimately associated, that if a malign influence act upon one, the effect is speedily extended to the other.

Owing to the necessity for the blood possessing certain attributes, the most important of which are obtained by its circulation through

the lungs, we can understand, that if the functions of nutrition be not properly exerted, the composition of that fluid may be imperfect, and disorder take place in various parts of the frame from this cause. Thus, if digestion or the formation of chyle be not properly executed, the blood is not duly renovated, and may be so far impoverished, that the play of the functions is interfered with. We have elsewhere shown, that if omnivorous man be restricted to one kind of diet he will fall off, and become scorbutic, and that the affection may be removed by allowing him diet of another kind;—vegetables, if animal food has induced it; and conversely. Enlarged mesenteric glands, consequent, or not, on inflammation of the mucous membrane of the intestine, and the latter affection itself, are cases which may interfere with chylosis, and consequently, with the constitution of the blood. In like manner, if nutrition and the various secretions be not duly performed in the tissues of the organs, and, especially, if the great depurations be obstructed the blood may suffer; and although the due change from venous to arterial may be effected in the lungs, its character may not be such as to adapt it for the healthy execution of the various functions.

The humorists assigned too much importance to the humors in the production of disease; the solidists, on the other hand, have denied them almost all agency. A medium between these exclusionists is probably the nearest the truth. The solitary fact of black blood being unfit to maintain the perfect and continued vitality of any organ sufficiently exhibits its influence. How the arterial blood exerts its agency, independently of its action as a fluid of nutrition, is beyond our knowledge. It appears to effect a necessary action of stimulation, but in what manner, or on what element, we know not: probably, however, its chief influence may be on the nervous tissue, as privation of arterial blood soon occasions the cessation of the brain's action.

In the higher classes of animals, innervation is dispensed from three great centres,—the encephalon, spinal marrow, and the great sympathetic. If the nervous supply be cut off from any part, the part dies. Physical integrity, continuity, and a due supply of arterial blood, are necessary for the proper exercise of the nervous power. In the former part of this work, the wonderful resistance to death which characterizes the amphibia, and the comparative independence of each portion of the body in some of the lower orders of animals, were pointed out. The polypus may be divided into numerous pieces, yet each may constitute of itself a distinct animal. The snail, after decapitation, reproduces the head; and a similar reparatory power is possessed by other animals. We have elsewhere seen, that volition is seated lower in the inferior than in the superior orders of animals; and that in man it is chiefly, if not wholly, restricted to the encephalon. It appears, likewise, that the dependence of the rest of the nervous system on the great nervous centres is less in young than in old animals. M. Edwards regarded the new-born child as resembling, in many respects, the cold-blooded animal; and Redi, Rolando and Flourens, and Legallois, found that the tenacity of life, after decapitation, was much greater the nearer to birth. The functions also differ with regard to their dependence upon the encephalon. Disease may attack the animal functions and suspend them for a considerable length of time,—as in apoplexy,—

before the organic functions are interfered with. The cerebro-spinal nervous system may cease to act, and life continue; but if the true spinal or reflex nervous system has its action suspended, respiration ceases, and death is inevitable. This is a topic, however, which will be discussed under the head of Death.

A gifted teacher of the author,—the late Professor Béclard,[1]—has defined life to "consist essentially in the reciprocal action of the circulation of the blood and innervation; death always following the cessation of such reciprocal action." But this conclusion is applicable only to animals; although both circulation and innervation are admitted in the vegetable by some physiologists. M. Legallois,[2] from his experiments, deduced the unwarrantable inference, that "life is owing to an impression made by arterial blood on the brain and spinal marrow, or to the principle, which results from this impression;"—a definition, that would exclude the numerous animals of the lower classes, as well as vegetables, which are deficient in both brain and spinal marrow. Some have endeavoured to discover which of the two functions,—circulation or innervation,—holds the other in domination. They, who consider the nervous substance to be first formed in the fœtus, ascribe the supremacy to it; whilst the believers in the earlier formation of the sanguiferous system look upon it as the prime agent. We know no more than that both

> "Maintain,
> With the mysterious mind and breathing mould,
> A co-existence and community."

Matter is, however, endowed with life, independently of the functions mentioned, as in the case of the materials furnished by both parents at a fecundating copulation; to which no one can deny the possession of a *Trieb*, impulse or life-power, before there are organs of either circulation or innervation.

In every important function of the body we find the correlation of organs existing,—all working to one end, and all requisite for its perfect accomplishment. How many organs, for example, are required to co-operate in the elevated function of sensibility! The encephalon, the seat of thought, receives, by the external senses, the various impressions that act upon them from without, and, by the internal sensations, such as arise in the economy, and are the indexes of physical necessities or wants. The intellectual and affective faculties enable us to appreciate the various objects that occasion our sensations, and to indicate our social and moral wants: under their direction, volition is sent out, which acts upon the various muscles, and produces such movements as may be required for carrying into effect the suggestions of the mind. Between all these acts there is the closest catenation. In like manner, we observe the correlation between the animal, nutritive, and reproductive functions. The internal sensation of hunger suggests to the mind the necessity for a supply of aliment; the external senses are called into action to discover the proper kind; when discovered, it is

[1] Elémens d'Anatomie Générale, 2de édit., Paris, 1827; or Togno's translation, p. 106, Philad., 1830.

[2] Sur le Principe de la Vie, Paris, 1812.

laid hold of by muscular movements under the direction of volition; is subjected to various voluntary processes in the mouth, and then passed on, by a mixed voluntary and involuntary action, into the stomach. In like manner, the desire for sexual intercourse may be excited through the organs of vision or touch; the organs of generation are aroused to action, and the union of the sexes is accomplished by the exertion of muscles thrown into contraction by volition. The same catenation is exhibited after a fecundating copulation; menstruation, which was previously performed with regularity, is arrested; the breasts become developed; milk is formed in them; and, whilst the female suckles her child, unless the period is unusually protracted, the arrest of the menstrual functions continues.

Almost all the phenomena of disease are connected with this correlation of functions. Derangement takes place in one organ or structure of the body, and speedily all those that are correlated with it participate in the disorder. Hence, in part, arises the combination of disordered nervous, circulatory, and secretory function, which characterizes general fever, and the various associated morbid actions that constitute disease in general.

3. SYMPATHY.

There is another kind of connexion, which distinguishes the animal body from a piece of ordinary mechanism still more than those we have considered. In this, owing to an impression made upon one organ, distant organs become affected, without our being able to refer the transmission to mechanical agency, or to the association of functions, which we have described. This kind of association is called *sympathy*. A particle of snuff or other irritating substance, impinging on the Schneiderian membrane, produces itching there, followed by a powerful action of the whole respiratory apparatus, established for its removal. The sneezing, thus induced, is not caused by the transmission of the irritation through the intermediate organs to the respiratory muscles; nor can we explain it by the mechanical or functional connexions of organs. It is produced by this third mode of correlation,—or by sympathy. Again, a small wound in the foot produces locked jaw, without our being able to discover, or to imagine, any greater connexion between the foot and the jaw, than between the foot and other organs of the body. We say, that this is caused by sympathy between these organs, and, so long as we use the term to signify the unknown cause of such connexions, it is well. It must be understood, however, that we attach no definite idea to the term; that it is only employed to express our ignorance of the agent or its mode of action; as we apply the epithet *vital* to a process, which we are incapable of explaining by any physical facts or arguments.

Of sympathetic connexions we have numerous examples in the body; at times, inservient to accomplishing a particular function; but generally consisting of modifications of function produced by the action of a distant organ. Of the sympathetic connexion between the parts of the same organ, for the execution of a function proper to that organ, we have an example in the iris and retina: the former contracts or dilates according to the degree of stimulation exerted by the light on the latter;

and the effect is greater when the light is thrown on the retina than on the iris itself. A similar kind of sympathy exists between the mammæ and uterus, during pregnancy, although this has been frequently referred to ordinary functional correlation or synergy; but the connexion is sufficiently obscure to entitle it to be placed under this division. A singular example of the sympathy between these two organs, soon after delivery, is the fact of the sudden and powerful contraction excited in the uterus, when in a state of inertness, by the application of the child to the breast.

a. *Sympathy of Continuity.*

This occurs between various parts of membranes that are continuous. For example, the slightest taste or smell of a nauseous substance may bring on an effort to vomit,—the whole of the first passages being unfavourably disposed for its reception. In disease, we have many examples of this kind of sympathy. During dentition, the child is subject to various gastric and intestinal affections. If a source of irritation exists in any part of the intestinal or other mucous membrane, no uneasy sensation may be experienced in the seat of irritation, yet it may be felt at the commencement of the membrane or where it commingles with the skin:—thus, itching at the nose may indicate irritation of the digestive mucous membrane;—itching or pain of the glans penis, stone in the bladder, &c. These facts prove, that, in disease, a sympathetic bond unites the parts concerned; and such is probably the case in health also. We have the same thing proved in the effect produced on the action of glands by irritating the orifices of their excretory ducts. The presence of food in the mouth excites the secretion of the salivary glands, and that of chyme in the duodenum augments the secretion of the liver. In the same manner, a purgative, as calomel, which acts upon the upper part of the intestinal canal, becomes a cholagogue; and duodenal irritation occasions a copious biliary secretion. These cases have, however, been considered by many to belong more appropriately to functional correlation; as it is presumable, that the propagation of the irritation from the orifice of the excretory duct takes place directly, and along branches of the same nerves as those that supply the glandular organs in question.

It is by the sympathy of continuity that we explain the action of certain medicines. In bronchial irritation, for example, the cough is frequently mitigated by smearing the top of the larynx with a demulcent,—the soothing influence of which extends to the part irritated.

b. *Sympathy of Contiguity.*

A variety of sympathy, differing somewhat from this, is the *sympathy of contiguity* or *contiguous sympathy*, in which an organ is affected by an irritation seated in another immediately contiguous to it. The association of action between the lining membrane of the heart and the muscular tissue of the organ has been given as an instance of this kind; and chiefly from the experiments of MM. Bichat and Nysten, which showed, that any direct irritation of the muscular tissue of the heart has not as much influence as irritation of the membrane that lines it. A similar association is presumed to exist between the mucous and mus-

cular coats of the alimentary canal; and the same kind of evidence is adduced to prove that the connexion is sympathetic. Other instances of sympathy are,—the convulsive contraction of the diaphragm and abdominal muscles in vomiting consequent on the condition of the stomach, as well as the convulsive action of the respiratory muscles in sneezing, coughing, &c. The general uniformity in the motion of the two eyes has been given as an additional instance; but M. Adelon[1] has judiciously remarked, that the evidence in favour of this view is insufficient. For clearness of vision it is necessary, that the luminous rays should impinge upon corresponding points of the two retinæ, and should fall as nearly as possible in the direction of the optic axes. For this purpose, the muscles direct the eyes in the proper manner; and subsequently, from habit, the eyeballs move in harmony. We constantly hear, also, a fact taken from pathology as an instance of sympathy. A molar tooth is lost on one side of the jaw; and it is found that the next tooth which decays is the corresponding molar of the opposite side:—or a tooth has become carious, and we find the one next to it soon afterwards in a course of decay. These have been regarded as evidences of sympathy,—remote and contiguous. This is not probable. The corresponding teeth of the two sides are similarly situate as regards the supply of nerves, vessels, and every anatomical element; and experience teaches us, that the molar teeth—and especially the second great molares—decay sooner than others. If one, therefore, becomes carious, we can understand why its fellow of the opposite side should be more likely to suffer. The opinion, that contiguous teeth are likely to be affected by the presence of a carious tooth, either by sympathy, or direct contact, is almost universally believed, and promulgated by the dentist. Both views are probably alike erroneous. If the inner side of the second molaris be decayed, we can understand why the corresponding side of the third should become carious, without having recourse either to the mysterious agency of sympathy, or to the very doubtful hypothesis of communication by contact,—especially as the caries generally begins internally. The contiguous sides of the teeth are situate almost identically as regards their anatomical elements; and, consequently, if a morbid cause affects the one, the other is more likely to suffer, and very apt to do so. Extracting the diseased tooth prevents this, because it removes a source of irritation, which could not but act in a manner directly injurious on the functions of the tooth next to it.

The fact of the sympathy that exists between organs of analogous structure and functions, is familiar to every pathologist. That of the skin and mucous membrane is intimate. In every exanthematous disease, the danger is more or less dependent upon the degree of affection of the mucous membranes; and the direct rays of the sun, beaming upon the body in warm climates, in this manner induce diarrhœa and dysentery. Acute rheumatism is a disease of the fibrous structures of the joints; but one of its most serious extensions, or metastases,—whichsoever they may be considered,—is to the fibrous structure of the pericardium. M. Barthez,[2] a most respectable writer, gives a case of this

[1] Physiologie de l'Homme, edit. cit., iv. 267, Paris, 1829.
[2] Nouveaux Elémens de la Science de l'Homme, Paris, 1806.

kind of sympathy from Theden, which is inexplicable and incredible. A patient, affected with paralysis of the right arm, applied a blister to it, which produced no effect, but acted on the corresponding part of the other arm. The left becoming afterwards paralysed, a blister was put upon it, which also acted upon the other arm, not on the one to which it was applied! Owing to the sympathy, or consent of parts, M. Broussais[1] has laid down the pathological law,—that when an irritation exists for a long time in an organ, textures analogous to the one diseased, are apt to contract the same affection.

c. *Remote Sympathies.*

As examples of the more remote kinds of sympathy, we may cite the effect produced on the stomach by distant organs, and conversely. Among the earliest signs of pregnancy are nausea and vomiting; loathing of food; fastidious appetite, &c. These phenomena are manifestly induced by sympathetic connexion between the uterus and stomach; inasmuch as they are not adventitious, but occur, more or less, in all cases of pregnancy. Their absence, at least, is a rare exception to the rule. Hunger or dyspepsia, again, impresses a degree of languor,—mental and corporeal,—which is proverbial; whilst the reception of food, and its vigorous digestion, give a character of energy and buoyancy, greatly contrasting with opposite circumstances. In disease, too, we find sympathies existing between the most distant portions of the frame, and although these are not apparent in health, we are perhaps justified in considering, that an occult sympathy exists between them in health, which only becomes largely developed, and obvious, when the parts are affected with disease. It is probable, too, that in the successive evolution of organs at different periods of life, new sympathies arise, that did not previously exist or were not observable. The changes in the whole economy at puberty illustrate this; changes that do not occur in those who, owing to malformation, are not possessed of the essential parts of the reproductive system, or who have had them removed prior to this period.

d. *Imagination.*

The effect of the intellectual and moral faculties on the exercise of the functions of other parts is strongly evidenced, especially in disease. The influence of the mind over the body is, indeed, a subject that demands the attention of every pathologist. In health, we notice the powerful effect induced by the affective faculties on every function. All these are caused by sympathetic association with the brain; the action of the organs being in a state of excitement or depression, according to the precise character of the emotion. The intellectual manifestations probably exert their influence in a manner less evident, but not less certain. The effects of one of them, at least, on the bodily functions are remarkable. We allude to the *imagination*, to which we can ascribe most of the cures said to have been effected by modes of management,—often of the most disgusting character,—which have

[1] Commentaires des Propositions de Pathologie; translation by Drs. Hays and Griffith, p. 60, Philada., 1832.

been from time to time in vogue; have fretted their hour on the stage, and then sunk into that insignificance from which they ought never to have emerged.

Occasion has been had to allude to the excited imagination of the maniac, the hypochondriac, and the nervous, and it was remarked, that hallucinations may exist in those of sound mind;—phantoms created by the imagination; pains felt in various bodily organs, &c.; and we can hence understand, that, under special circumstances, we may have actual disease produced in this manner; and, at other times, the feeling,—which may be as distressing to the patient,—of disease, which has no existence except in the imagination. It is to the effect produced by the imagination, that we must ascribe the introduction into medicine of magic, sorcery, incantations, Perkinism, and other offsprings of superstition or knavery. The enthusiasm, that has attended the application of these modes of acting on the imagination in our own times, is extraordinary, and their history leads us to be still more impressed with the extensive influence that may be exerted by the mind over the body: they teach the practitioner the importance of having its co-operation, whenever it can be procured; and the disadvantages, which he may expect to ensue, when the imagination is either arrayed against himself personally, or the plan of treatment he is adopting. The physician, who has the confidence of his patient, may be successful—if he adopts precisely the same plan of treatment that would be pursued by one who has it not—in cases where the latter would totally fail. The applications of this subject are developed by the author elsewhere.[1]

Again, pathology is invoked as affording us perhaps the best evidences of the existence between various parts of the frame of extensive sympathetic relations, that may be constantly going on unseen during health, but become developed, and obvious in disease. The case, previously given, of the general effects produced on the system by local irritation of a part, shows the extent of such association. An insignificant portion of the body may become inflamed, and if the inflammation continues, the functions of the stomach may be disordered,—as indicated by loss of appetite, nausea, and vomiting; the respiration be hurried, as well as the circulation; the senses blunted; the intellectual and moral faculties obscured; and languor and lassitude indicate the nervous irritation and constraint.

The moral consideration of sympathy does not immediately concern the physiologist. It is a subject,—and one of interest—to the moral philosopher, to account not only for the secret causes, that attract individuals towards each other, but that repel them and occasion *antipathies*. To a certain extent, however, it trends into the province of the physiologist. The tender, susceptible individual, from observing another suffering under pain, feels as if labouring under the same inconvenience; and, by a very rapid, yet complex intellectual process, constituted of numerous associations, may be so strongly impressed as to sink under their influence:—thus, the sight of blood so powerfully impresses the mind of some, in this sympathetic manner, that fainting

[1] General Therapeutics and Materia Medica, 5th edit., Philada., 1853.

may be induced, and the vital functions be for a time suspended. The sight and suffering of a woman in labour may cause abortion in another; and hence the propriety of excluding those who are pregnant from the chamber of the parturient female. Hysteric and convulsive paroxysms are induced in a similar way; of which the *convulsionnaires* of all times must be regarded as affording singular and instructive examples.

e. *Superstitions connected with Sympathy.*

Lastly:—The mysterious consent, observed between various parts of the body, has given rise to some strange and absurd superstitions. It was believed, for instance, almost universally, in the fifteenth century, that an intimate sympathy exists, not only between parts of a body forming portions of one whole, but also between any substance that had previously formed part of a body and the body itself;—that if, for example, a piece of flesh were sliced from the arm of one person, and made to unite with that of another, the grafted portion would accurately sympathize with the body of which it had previously formed part, and undergo decay and death along with it; and it was even proposed to turn this sympathy to account. It was recommended, for instance, that the alphabet should be traced on the ingrafted portion; and it was affirmed, that when any of the letters, so traced, were touched, the party from whom the piece of flesh had been taken would feel similar impressions; so that, in this manner, a correspondence might be maintained. Some went even farther than this, asserting, that such a miraculous sympathy exists between the human body and all that has previously formed part of it, that if a hot iron were run into the excrement, he would feel a sensation of burning in the part whence it had proceeded!

It was also a notion, that grafts of flesh, united to the body of another, died when the person died from whom they had been taken. In a work on animal magnetism, the case of a man at Brussels is given, who had an artificial nose formed after the old Taliacotian method, which served every useful purpose, until the person, from whom the graft had been taken, died, when it suddenly became cold and livid, and fell off. Tagliacozzi[1] himself lived in an era of superstition, when this belief in the simultaneous death of the parent and graft was universally credited; and the folly has not escaped the notice of Butler:

> "So learned Taliacotius from
> The brawny part of porter's bum,
> Cut supplemental noses, which
> Would last as long as parent breech;
> But when the date of nock was out,
> Off dropped the sympathetic snout."—*Hudibras.*

But the power of sympathy has been conceived to extend farther. The magical influence of the will of one person over another was credited by such men as Bacon, who lived in the very era of luxuriant superstition, and the belief has been resuscitated at the present day. It has been credited, for example, that when a person is in a magnetic

[1] Gasparis Taliacoti Bononiensis De Curtorum Chirurgiâ per insitionem libri duo, Venet., 1597.

or mesmeric state, it is but necessary for the magnetizer to will that the magnetized person shall execute some act, and it is immediately accomplished. Nay, that a magnetized individual may be taken at the will of one, with whom he is placed in communion or *rapport*, to a distance, and describe scenes and objects, which he had never witnessed, exactly as those scenes and objects really are; taste, smell, feel, and see objects, that are tasted, smelt, felt, and seen by another; and be wafted even to "any or all the heavenly bodies of which we have any knowledge;" and it has been gravely affirmed by a veteran teacher[1] in his enthusiasm on the subject, that "such deeds as these may well be called amazing, yet are they as easy, certain, and speedy of performance, as many of the most common transactions of life." Yet the evidence is totally insufficient to establish the existence of the slightest shade of such mysterious sympathy.[2]

Not less singular was the superstition,—that the wounds of a murdered person will bleed afresh if the body be touched ever so lightly, in any part, by the murderer. This idea gave rise to the trial by *bier-right*, which has been treated by Sir Walter Scott with so much dramatic skill in one of his novels,—*St. Valentine's Day, or the Fair Maid of Perth*. The annals of judicial inquiry furnish us with many instances of this gross superstition.[3] A case of the kind occurred in this country. It is stated in the attestation of John Demarest, coroner of Bergen county, New Jersey.[4] The superstition is noticed, too, by many of the older poets. Thus, Shakspeare,—where the Lady Anne reviles Gloster over the corpse of Henry:—

> "O! gentlemen, see, see! dead Henry's wounds
> Open their congeal'd mouths and bleed afresh!
> Blush, blush, thou lump of foul deformity;
> For 'tis thy presence that exhales this blood
> From cold and empty veins, where no blood dwells.
> Thy deed, inhuman and unnatural,
> Provokes this deluge most unnatural."
>
> RICHARD III., i. 2.

And Webster, in a tragedy published about the middle of the seventeenth century:—

> "See
> Her wounds still bleeding at the horrid presence
> Of yon stern murderer, till she find revenge."
>
> APPIUS AND VIRGINIA.

The belief in these cases of monstrous superstition, which, it need scarcely be said, are explicable on purely physical principles, or on the excited imagination of observers, still exists amongst the benighted inhabitants of many parts of Great Britain and Ireland, and is the main topic of one of the second series of "*Traits and Stories of the Irish Peasantry*." The superstition has, indeed, its believers among us. On the trial of Getter, who was executed in 1833 in Pennsylvania, for the murder of his wife, a female witness deposed on oath, as follows:—"If

[1] Caldwell, Facts in Mesmerism, and Thoughts on its Causes and Uses, Louisville, 1842.

[2] The Author's Medical Student, new edit., p. 250, Philad., 1844.

[3] See the case of Philip Stansfield for the Murder of his Father, Sir James Stansfield, in Hargrave's State Trials, iv. 283; and in Celebrated Trials of all Ages, &c., ii. 566, Lond., 1825.

[4] Annual Register, for 1767.

my throat was to be cut, I could tell, before God Almighty, that the deceased smiled, when he (the murderer) touched her. I swore this before the justice, and that she bled considerably. I was sent for to dress her and lay her out. He touched her twice. He made no hesitation about doing it. I also swore before the justice, that it was observed by other people in the house."

It would be endless to enumerate the various superstitions, that have prevailed on topics more or less remotely connected with this subject. We pass on to the interesting, but abstruse, inquiry into the

f. *Agents by which Sympathy is accomplished.*

The opinions of physiologists have, from time to time, rested chiefly on the membranes, areolar tissue, bloodvessels, and nerves; but there have been some, who, in the difficulty of the subject, have supposed sympathy to be devoid of organic connexion; and others, again, have presumed, that all the parts mentioned are concerned. The rapidity, however, with which sympathies are evidenced, has led to the abandonment of all those opinions; and the generality of physiologists of the day look to the nervous system as the great source and medium of communication of the different irradiations by which distant organs are supposed to react, in this manner, on each other. The rapidity, indeed, with which the various actions of the nervous system are executed,—the apparent synchronism between the reception of an impression on an organ of sense, and its perception by the brain; as well as between the determination of the will and its effect upon a muscle,—naturally attracted attention to this system as the instrument of sympathy.

The modes, in which sympathy is supposed to be accomplished, are;—either by the parts that sympathize receiving ramifications from the same nervous trunks, or from such as are united by nervous anastomoses; or by the nervous irradiations, emanating from one organ, proceeding to the brain, and being thence reflected to every dependency of the system, but in such sort, that certain organs are more modified by the reflection than others; hence, the distinction into what have been termed *direct sympathies* and *cerebral sympathies.*

Of direct sympathies we have already given examples,—as that between the mucous and muscular coats of the intestines; and if our acquaintance with the precise distribution and connexion of the various parts of the nervous system were more intimate, we might perhaps explain many of the cases that are yet obscure. The researches of Sir Charles Bell regarding the nerves concerned in respiration have thrown light on the associations of organs in the active exercise of the respiratory function. It has been elsewhere shown, that although the whole of the nerves, composing his *respiratory system*, may not be apparently in action during ordinary respiration, yet when the function has been greatly excited, the association becomes obvious. The opinion of Boerhaave, Meckel, and some others, is, that all sympathies are accomplished in this direct manner. On the other hand, Haller, Whytt, Georget, Broussais, Adelon, and others, think, that the majority of sympathies are produced through the medium of the brain.

Dr. Bostock[1] indeed affirms, that the facts, adduced by Whytt,[2] are of such a nature as "to prove, that the co-operation of the brain is essential in those actions, which we refer to the operation of sympathy." In many cases, this is, doubtless, the fact;—as in sneezing and coughing; but there are others in which such co-operation seems improbable and indeed impossible. Something like sympathy exists in the vegetable; in which if we admit, with some naturalists, a rudimental nervous system, we have no reason for presuming, that there is anything like a centre for the reception or transmission of impressions; and the case of infants born devoid of brain and spinal cord affords evidence of a like description.

We find, that the influence of the vital principle is exemplified in the formation of a body of a certain magnitude, form, structure, composition and duration; and that this applies to all organized bodies, vegetable as well as animal. Where such appearance of design, consequently, exists, we ought to expect, that in the vegetable, also, a harmony or consent must reign amongst the various functions that tend to the production of the uniformity, which enables us to recognise the particular varieties of the vegetable kingdom, and has kept them as distinct, probably, in their characters, as when first created by Almighty power. The irritation of a single leaflet of the *Mimosa pudica* or *sensitive plant* causes the whole leaf, as well as the footstalk, to contract. Dr. John Sims irritated a leaflet of this plant, taking the greatest pains to avoid moving any other part of the leaf; yet the whole contracted, and the footstalk dropped. In order, however, to be sure, that mechanical motion communicated by the irritation had no share in the contraction, he directed a sunbeam, concentrated by a lens, on one of the leaflets, when the leaf again contracted, and the footstalk dropped. Of this kind of vegetable irritability we have many examples, some of which are alluded to under another head.

From these and other facts of an analogous character, Sir Gilbert Blane[3] concludes, that the functions of living nature, in all its departments, are kept up by a mutual concert and correspondent accordance of every part with every other part;—that it would be in vain to waste time in endeavouring to account for them by groping among dark analogies and conjectures; and that it is better to assume them as facts, on which are founded the ultimate and inscrutable principles of the animal economy. We have certainly much to learn regarding the agents of sympathies, and the modes in which they are effected; but still we know enough to infer, that in many cases, in animals, the nerves appear to be the conductors; that the brain is, in others, the centre to which the organ in action transmits its irradiations, and by which they are reflected to the sympathizing organ; and that in others, again, the effect is caused in the absence of nervous centre, and even of nerves, by vibrations perhaps, but in a manner which, in the present state of our knowledge, is inexplicable, and is, therefore, supposed to be essentially *organic* and *vital*,—epithets, however, as we have more than once said, that merely convey a confession of our ignorance of the processes to which they are appropriated.

[1] Elementary System of Physiology, 3d edit., p. 762, Lond., 1836.
[2] An Essay on the Vital and other Involuntary Functions, § xi., Edinb., 1751.
[3] Elements of Medical Logic, 3d edit., Lond., 1819.

CHAPTER IV.

INDIVIDUAL DIFFERENCES AMONGST MANKIND.

THE differences observed amongst the individuals of the great human family are as numerous as the individuals themselves; but this dissimilarity is not confined to man or to the animal kingdom: the vegetable exhibits the same; for, whilst we can readily refer any plant to the species and variety, to which it may have been assigned by the botanist, accurate inspection shows that in the precise arrangement of the stalks, branches, leaves, or flowers, no two are exactly alike. We shall not, however, dwell on these trifling points of difference, but restrict ourselves to the broad lines of distinction that can be easily observed, and an attention to which is of some moment to the physician. Such are the *temperaments*, *constitutions*, *idiosyncrasies*, *acquired differences*, and *varieties of the human species* or the *different races of mankind.* Of these, the last belong more especially to the natural historian; and, consequently, will be but briefly noticed.

1. TEMPERAMENTS.

The temperaments are defined to be,—those individual differences, which consist in such disproportion of parts, as regards volume and activity, as to modify sensibly the whole organism, but without interfering with the health. Temperament is, consequently, a physiological condition, in which the action of the different functions is so *tempered* as to communicate certain characteristics, that may be referable to one of a few divisions. These divisions are by no means the same in all physiological treatises. The ancients generally admitted four,—denominated from the respective fluids or humours, the superabundance of which in the economy was supposed to produce them;—the *sanguineous*, caused by a surplus of blood; the *bilious* or *choleric*, produced by a surplus of yellow bile; the *phlegmatic*, caused by a surplus of phlegm, lymph, or fine watery fluid, derived—it was conceived—from the brain; and the *atrabiliary* or *melancholic*, produced by a surplus of black bile,—the supposed secretion of the atrabiliary capsules and spleen. This division was kept up for ages without modification; and still prevails with one or more additional genera. The epithets have been retained in popular language without our being aware of their parentage. For example, we speak of a *sanguine*, *choleric*, *phlegmatic*, or *melancholic* individual or turn of mind with nearly the acceptation given to them by the Hippocratic school,—the possessors of these temperaments being presumed to be, respectively, full of high hope and buoyancy; naturally irascible, dull and sluggish; or gloomy and low-spirited. Metzger admits only two,—the *irritable* (reizbare), and the *dull* or *phlegmatic* (träge). Wrisberg[1] eight,—the *sanguine*, *sanguineo-choleric*, *choleric*, *hypochondriac*, *melancholic*, *Bœotian*, *meek*, (sanftmüthige,) and the *dull* or *phlegmatic*. Rudolphi[2] also eight,—

[1] In his edition of Haller's Grundriss der Physiologie.

[2] Grundriss der Physiologie, 1er Band., S. 258, Berlin, 1821.

the *strong* or *normal;* the *rude, athletic*, or *Bœotian;* the *lively;* the *restless;* the *meek;* the *phlegmatic* or *dull;* the *timorous*, and the *melancholic;*—whilst M. Broussais[1] enumerates the *gastric, bilious, sanguine, lymphatico-sanguine, anæmic, nervous, bilioso-sanguine, nervoso-sanguine*, and *melancholic*. It is obvious, that if we were to apply an epithet to the possible modifications caused by every apparatus of organs, the number might be extended much beyond any of these. Perhaps the division most generally adopted is that embraced by M. Richerand,[2] who has embodied considerable animation, with much that is fanciful, in his description. In this division, the ancient terms have been retained, whilst the erroneous physiological basis, on which they rested, has been discarded. A short account of these temperaments is necessary, rather for the purpose of exhibiting what has been, and is still, thought by many physiologists, than for attesting the reality of many of the notions that are mixed up with the subject. With this view, the temperaments may be divided into the *sanguine, bilious* or *choleric, melancholic, phlegmatic*, and *nervous*.

a. *Sanguine Temperament.*

This is supposed to be dependent upon a predominance of the circulatory system; and hence is considered to be characterized by strong, frequent, and regular pulse; ruddy complexion; animated countenance; good shape, although distinctly marked; firm flesh; light hair; fair skin; blue eyes; great nervous susceptibility, attended with rapid *successibilité*, as the French term it, that is,—a facility of being impressed by external objects, and passing rapidly from one idea to another; quick conception; ready memory; lively imagination; addiction to the pleasures of the table; and amorousness. The diseases of this temperament are generally violent; and chiefly implicate the circulatory system,—as fevers, inflammations, and hemorrhages. Its physical traits, according to M. Richerand, are to be found in the statues of Antinous and the Apollo Belvidere: the moral physiognomy is depicted in the lives of Mark Antony and Alcibiades. In Bacchus, both the forms and character are found; and no one in modern times, in M. Richerand's opinion, exhibits a more perfect model of it than the celebrated Duke de Richelieu;—amiable, fortunate and valorous, but light and inconstant to the termination of his brilliant career.

If individuals of this temperament apply themselves to labours of any kind that cause the muscles to be greatly exerted, these organs become largely developed, and a subdivision of the sanguine temperament is formed, which has been called the *muscular* or *athletic*. This is characterized by all the outward signs of strength: the head is small; the neck strong; the shoulders broad; the chest large; the hips solid; the muscles prominent, and the interstices well marked. The joints, and parts not covered with muscles, seem small; and the tendons are easily distinguished through the skin by their prominence. The susceptibility to external impressions is not great; the individual is not

[1] Traité de Physiologie, translation by Drs. Bell and La Roche, 3d edit., p. 561, Philad., 1832.

[2] Nouveaux Elémens de Physiologie, 13ème édit. par M. Bérard ainé, § ccxxviii., Bruxelles, 1837.

easily roused; but when he is, he is almost indomitable. A combination of the physical powers, implied by this temperament, with strong intellect, is rarely met with.

The Farnesian Hercules is conceived to offer one of the best specimens of the physical attributes of the athletic temperament.[1]

b. *Bilious* or *Choleric Temperament.*

This is presumed to be produced by a predominance of the liver and biliary organs. The pulse is strong, hard, and frequent; the subcutaneous veins are prominent; the skin is of a brown colour inclining to yellow; hair dark; body moderately fleshy; muscles firm, and well marked; passions violent, and easily excited; temper abrupt and impetuous; great firmness and inflexibility of character; boldness in the conception of projects, and untiring perseverance in their fulfilment. It is amongst the possessors of this temperament, that the greatest virtues and the greatest crimes are met with. The moral faculties are early developed, so that vast enterprises may be conceived, and executed at an age when the mind is ordinarily far from being matured. The diseases are generally combined with more or less derangement of the hepatic system. The whole of the characters, however, indicate, that an excited state of the sanguiferous system accompanies that of the biliary organs; so that the epithet *cholerico-sanguine* might, with more propriety, be applied to it. Where this vascular predominance does not exist, and derangement is present in some of the abdominal organs, or in the nervous system, we have the next form produced.

M. Richerand[2] enumerates Alexander, Julius Cæsar, Brutus, Mahomet, Charles XII., Peter the Great, Cromwell, Sextus V., and the Cardinal Richelieu. To these, Dr. Good[3] has added Attila, Charlemagne, Tamerlane, Richard III., Nadir Shah, and Napoleon.

c. *Melancholic* or *Atrabilious Temperament.*

Here the vital functions are feebly or irregularly performed; the skin assumes a deeper hue; the countenance is sallow and sad; the bowels are torpid; and all the excretions tardy; the pulse is hard, and habitually contracted; the imagination gloomy, and the temper suspicious. The characters of Tiberius and Louis XI. are considered to be examples of predominance of this temperament; and, in addition to these, M. Richerand[4] has enumerated Tasso, Pascal, Gilbert, Zimmermann, and Jean Jacques Rousseau.

d. *Phlegmatic*, *Lymphatic* or *Pituitous Temperament.*

In this case, the proportion of the fluids is conceived to be too great for that of the solids;—the secretory system appearing to be active, whilst the absorbent system does not act so energetically as to prevent the areolar texture from being filled with humours. The characteristics of the temperament are:—soft flesh; pale skin; fair hair; weak, slow, and soft pulse; figure rounded, but inexpressive; vital actions more or less languid; memory by no means tenacious; attention vacil-

[1] Richerand, op. citat., § ccxxix.
[2] Op. cit., § ccxxx.
[3] Book of Nature, 3d edit., iii. 276, Lond., 1834.
[4] Op. citat., ccxxxi.

lating; with aversion to both mental and corporeal exertion. Pomponius Atticus—the friend of Cicero—is offered as an example of this temperament, in ancient times; Montaigne, in more recent. The latter, however, possessed much of the nervous susceptibility that characterizes the more lively temperaments. Dr. Good[1] suggests the Emperor Theodosius as an example in earlier times; and Charles IV. of Spain, who resigned himself almost wholly into the hands of Godoy,—Augustus, King of Saxony, who equally resigned himself into the hands of Napoleon; and Ferdinand of Sicily, who surrendered for a time the government of his people to the British,—as instances in our own day. It would not be difficult to find amongst the crowned heads of Europe, others that are equally entitled to be placed amongst these worthies.

e. *Nervous Temperament.*

Here the nervous system is greatly predominant; the susceptibility to excitement from external impressions being unusually developed. Like the melancholic temperament, however, this is seldom natural or primitive. It is morbid or secondary, being induced by sedentary life, sexual indulgence, or morbid excitement of the imagination from any cause. It is characterized by small, soft, and, as it were, wasted muscles; and generally, although not always, by a slender form; great vividness of sensation; and promptitude and fickleness of resolution and judgment. This temperament is frequently combined with some other. The diseases that are chiefly incident to it are of the hysterical and convulsive kind; or those to which the epithet *nervous* is usually appropriated. Voltaire and Frederick the Great are given by M. Richerand[2] as examples of it.

Such are the temperaments described by most writers. The slightest attention to their reputed characteristics shows the imperfection of their definition and demarcation; so imperfect, indeed, are they, that it is extremely rare to meet with an individual, whom we could unhesitatingly refer to any one of them. They are also susceptible of important modifications by climate, education, &c., and may be so combined as to constitute innumerable shades. The man of the strongest sanguine characteristics may, by misfortune, assume all those that are looked upon as indexes of the melancholic or atrabilious; and the activity and impetuosity of the bilious temperament may, by slothful indulgence, be converted into the lymphatic or phlegmatic. It is doubtful, and more than doubtful, also, whether any of the mental characteristics assigned to the temperaments are dependent upon them. The brain, we have elsewhere seen, is the organ of the mental and moral manifestations; and although we may look upon the temperaments as capable of modifying its activity, they cannot probably affect the degree of perfection of the intellect;—its strength being altogether dependent upon the morphology of the brain. It is even doubtful whether the temperaments can interfere with the activity of the cerebral functions. In disease of the hepatic, gastric, or other viscera we

[1] Op. citat., iii. 280.

[2] Op. cit., ccxxxiii.

certainly see a degree of mental depression and diminished power of the whole nervous system; but this is the effect of a morbid condition, and continues only so long as such morbid condition endures. Nor is it probable, that any predominance of the nutritive functions could exert a permanent influence on the cerebral manifestations. Whatever might be the effect for a while, the nervous system would ultimately resume the ordinary action that befitted its primitive organization. Similar reasons to those induced the author's friend M. Georget,[1] a young physician of great promise and experience in mental affections, now no more,—to consider the whole doctrine of the temperaments as a superstition connected with the humoral pathology, and to believe, that the brain alone, amongst the organs, has the power, by reason of its predominance or inferiority, to modify the whole economy. That a difference of organization exists in different individuals is obvious; but that there is an arrangement of the nutritive organs or apparatuses, which impresses upon individuals all those mental and other modifications known under the name of temperaments, is, we think, sufficiently doubtful.

The *constitution* of an individual is the mode of organization proper to him. A man, for example, is said to have a robust, or delicate, or a good, or bad constitution, when he is apparently strong or feeble, usually in good health, or liable to frequent attacks of disease. The varieties in constitution are, therefore, as numerous as the individuals themselves. A strong constitution is considered to be dependent upon the due developement of the principal organs of the body, on a happy proportion between those organs, and on a fit state of energy of the nervous system; whilst the feeble or weak constitution results from a want of these. Our knowledge, however, of these topics, is extremely limited, and concerns the pathologist more than the physiologist.

2. IDIOSYNCRASY.

The word *idiosyncrasy* is used by many physiologists synonymously with constitution: but it is generally appropriated to the peculiar disposition, that causes an individual to be affected by extraneous agents, in a way in which mankind in general are not acted upon by these agents.

> "Some love not a gaping pig,
> And others, when the bagpipe sings i' th' nose,
> Cannot contain their urine for affection."
>
> SHAKSPEARE.

In all cases, perhaps, these peculiarities are dependent upon inappreciable structure, either of the organ concerned, or of the nervous branches distributed to it; at times, derived from progenitors; at others, acquired,—and often by association,—in the course of existence. Hence arise many of the antipathies to particular animate and inanimate objects, which we occasionally meet with, and of which M. Broussais relates a singular instance in a Prussian captain, whom he saw at Paris in 1815. He could not bear the sight of a cat, a thimble, or an old woman, without becoming convulsed, and making frightful grimaces! The associations must have been singularly complicated to

[1] De la Physiologie du Système Nerveux, &c., Paris, 1821.

occasion an antipathy to objects differing so signally from each other. Wagner,[1] of Vienna, has collected a multitude of cases of idiosyncrasy; and the observation of every one, whether of the medical profession or not, must have made him acquainted with those peculiarities that render a particular article of diet, which is innoxious, and even agreeable and wholesome to the generality of individuals, productive, in some, of the most unpleasant effects. Haller knew a person who was always violently purged by the syrup of roses. A friend of the author is purged by opium, which has an opposite effect on the generality of persons. Dr. Paris[2] says he knew two cases, in which the odour of ipecacuanha always produced most distressing dyspnœa; the author knew a young apothecary, who could never powder this drug without the supervention of the most violent catarrh; and Dr. Felix Robertson, of Tennessee,[3] has described his own case, in which violent asthma, attended with the most distressing dyspnœa and oppression at the præcordium, was induced by breathing the dust of ipecacuanha. Wine of ipecacuanha, taken as an emetic, occasioned, from the moment he swallowed it, "in the throat and stomach a sensation totally indescribable, but as intolerable to be borne (if life could have been sustained under it)" as if he had taken a drink of melted lead. The distress gradually subsided into one of his worst attacks of asthma. Yet, what is singular, until the time it first produced these effects, Dr. Robertson had been able to handle ipecacuanha with freedom and impunity. A friend of Tissot could not take sugar without its exciting violent vomiting. Urticaria or nettle-rash is very frequently occasioned, in particular constitutions by eating shell-fish. The same effect is produced on two female friends of the author by eating strawberries; and similar cases are given by Roose. M. Chevalier relates the case of a lady, who could not take powdered rhubarb without an erysipelatous efflorescence showing itself, almost immediately, on the skin; yet she could take it in the form of infusion with perfect impunity.

The above idiosyncrasies apply, however, only to the digestive function. We find equal anomalies in the circulation. In some, the pulse is remarkably quick, upwards of one hundred in a minute; in others, it is under thirty. That of Napoleon is said to have beaten only forty-four times in a minute.[4] It may also be unequal, and intermittent, and yet the individual be in a state of health.

The senses offer some of the most striking cases of this kind of peculiarity. Many strong individuals cannot bear the smell of the apple, cherry, strawberry, musk, or peppermint. Pope Pius VII. had such an antipathy to musk, that on the occasion of a presentation, an individual of the company having been scented with it, his holiness was obliged to dismiss the party almost immediately.[5] The late Lord Selkirk told Sir George Lefevre, that one of the most robust and indefatigable

[1] Hufeland and Himly's Journal der Pract. Heilkund., Nov., 1811, § 55.

[2] Pharmacologia, 4th Amer. edit. by J. B. Beck, p. 189, New York, 1831.

[3] Western Journ. of Med. and Surg., Aug., 1843.

[4] See some cases of unusual slowness of pulse, by Mr. H. Mayo, in Lond. Medical Gazette, May 5, 1838, p. 232; and in Amer. Med. Intel., July 2, 1838, p. 103. In one case of fatal disease the pulse beat only nine in a minute!

[5] Matthew's Diary of an Invalid.

of the Northwest Company's agents could not sit in the room, if salmon were on table. He had been known to faint under such circumstances.[1] The idiosyncrasies of taste are also numerous; and some instances of singular depravation of the sense have been described under the Sense of Taste. M. Dejean gives the case of an individual of distinguished rank, who was fond of eating excrement. Certain animals, again, as the turkey, have an antipathy to the colour of red; and Von Buchner and Tissot cite the case of a boy who was subject to epileptic fits whenever he saw anything of a red colour. Occasionally, we meet with similar idiosyncrasies of audition. Sauvages relates the case of a young man labouring under intense headache and fever, which could not be assuaged by any other means than the sound of a drum. The noise of water issuing from a pipe threw M. Bayle into convulsions. The author has a singular peculiarity of the kind, derived from accidental association in early life. If a piece of thin biscuit be broken in his presence,—nay, the idea alone is sufficient,—the muscles that raise the left angle of the mouth are contracted; and this irresistibly. Nor is the sense of tact free from idiosyncrasies. Wagner cites the case of a person, who felt a sensation of cold along the back, whenever he touched the down of a peach with the point of his finger; or when the down came in contact with any part of his skin. He was remarkably fond of the fruit, yet was unable to indulge his appetite unless another person previously removed the skin. Prochaska relates the case of a person, who was affected with nausea whenever he touched this fruit.

It is, of course, all important that the practitioner should be acquainted with these idiosyncrasies; and so far the notion of "knowing the constitution,"—which is apt to be used to the prejudice of the young practitioner, or of any except the accustomed medical attendant,—has some reason in it. It is the duty, however, of the patient to put the physician in the possession of the fact of such peculiarities, so that he may be enabled to guard against them, and not take that for morbid which is the effect of simple idiosyncrasy. This, however, is a topic which belongs rather to therapeutics.[2]

3. OF NATURAL AND ACQUIRED DIFFERENCES.

a. *Natural Differences.*

The temperaments, constitutions, and idiosyncrasies may, as we have seen, either be dependent upon original conformation, or they may be produced by external influences; hence, they have been divided into the *natural* and the *acquired*. Under the former head are included all those individual differences, derived from progenitors, which impress more or less resemblance to one or both parents. It has been properly observed, that the individuality of any human being that ever existed was absolutely dependent on the union of one particular man with one particular woman; and that if either the husband or the wife had been different, a different being would have been ushered into existence. For the production of Shakspeare, or Milton, or Newton, it was necessary that the father should marry the identical woman he did marry.

[1] An Apology for the Nerves, by Sir George Lefevre, M. D., p. 101, Lond., 1844.

[2] See the Author's General Therapeutics and Materia Medica, 5th edit., Philad., 1853.

If he had selected any other wife, there would have been no Shakspeare, no Milton, no Newton. Sons might have been born of other women, but they would not have been the same, either in mental or physical qualities. All this, however, enters into the question of the influence of both parents on the fœtus in utero; which we have considered elsewhere.

1. *Peculiarities of the Female.*

Amongst the natural differences, those that relate to *sex* are the most striking. In a previous part of this volume, we have described the peculiarities of the sexual functions in both male and female, but other important differences have not been detailed. All the descriptions, when not otherwise specified, were presumed to apply to the adult male. At present, it will be only necessary to advert to the peculiarities of the female.

The stature of the female is somewhat less than that of the male, the difference being estimated at about a twelfth. The chief parts of the body have not the same mutual proportions. The head is smaller and rounder; the face shorter; the trunk longer, especially the lumbar portion, and the chest more convex. The lower extremities, especially the thighs, are shorter, so that the half of the body does not fall about the pubes, as in man, but higher. The neck is longer; the abdomen broader, larger, and more prominent; and the pelvis has a greater capacity, to adapt it for gestation and parturition. The long diameter of the brim is from side to side, whilst, in the male, it is from before to behind; the arch of the pubis is larger, and the tuberosities of the ischia are more widely separated, so that the outlet of the pelvis is larger than in the male; the hips are broader, and, consequently, the spaces between the heads of the thigh-bone greater; the knees are more turned in, and larger than in the male; the legs shorter, and the feet smaller. The shoulders are round; but the width across them, compared with that of the hips, is not so great as in man; the arms are shorter, fatter, and more rounded; the same is the case with the forearm; the hand is smaller, and softer, and the fingers are more delicate. The whole frame is more slender; the bones are smaller, their tissue is less compact, and the prominences and corresponding depressions are less marked; the subcutaneous areolar tissue is more abundant, and filled with a whiter and firmer fat; a similar adipose tissue fills up the intervals between the muscles, so that the whole surface is rounder, and more equable than that of the male; the skin is more delicate, whiter, better supplied with capillary vessels, and less covered with hair; the hair of the head, on the other hand, is longer, finer, and more flexible; the nails are softer and of a more red hue; the muscles of the face are less distinctly marked, so that the expression of the eye, and the emotions that occasion elevation or depression of the angles of the mouth,—laughing and weeping, for example,—are more strongly defined. On the whole, the general texture of the organs is looser and softer.

The above observations apply to what may be termed the *standard female*,—one whose natural formation has not been interfered with by employments, that are usually assigned to the other sex. It can be readily understood, that if the female has been accustomed to laborious

exercise of her muscles, they may become more and more prominent, the interstices between them more and more marked; the projections and depressions of the bones on which they move more distinct; the whole of the delicacy of structure may be lost; and the skeleton of one thus circumstanced, may be scarcely distinguishable from that of the inactive male, except in the proportions of the pelvis, in which the sexual differences are chiefly and characteristically situate.

Many of the functions of the female are no less distinctive than the structure. The senses, as a general rule, are more acute, whether from original delicacy of organization, or from habit, is not certain; probably both agencies are concerned. The intellectual and moral faculties are also widely different; and this, doubtless, from original conformation, although education may satisfactorily account for many of the differences observable between the sexes. Gall is one of the few anatomists who have attended to the comparative state of the cerebral system in the sexes; and the results of his investigations lead him to affirm, that there is a striking difference in the developement of different parts of the encephalon in the two, which he thinks may account for the difference observable in their mental and moral manifestations. In the male, the anterior and superior part of the encephalon is more developed; in the female, the posterior and inferior: the former of these he conceives to be the seat of the intellectual faculties; the latter of those feelings of love and affection that seem to preponderate in the character of the female. We have elsewhere said, that the views of Gall on this subject are not yet received as truths, and that we must wait until further experience and multitudinous observations shall have exhibited their accuracy, or want of foundation. Independently, however, of all considerations deduced from organization, observation shows, that the female exhibits intellectual and moral differences which are by no means equivocal. The softer feelings predominate in her, whilst the intellectual faculties have the preponderance in man. The evidences and character of the various shades of feeling and susceptibility, and the influence of education and circumstances on these developements, are interesting topics for the consideration of the moral philosopher, but admit of little elucidation from the labours of the physiologist. The only inference at which he can arrive is, that the causes of the diversity are laid in organization, and become unfolded and distinctive by education. The precise organization he is unable to depict, and the influence of circumstances on the mind it is scarcely his province to consider.

The function of muscular motion is, owing to more delicate organization, more feebly executed in the female. We have already remarked, that the bones are comparatively small, and the muscles more delicately formed. The energy of the nervous system is also less; so that all the elements for strong muscular contraction are by no means in the most favourable condition; and, accordingly, the power the female is capable of developing by muscular contraction is much less than that of the male. Her locomotion is somewhat peculiar,—the wide separation of the hip-joints, owing to the greater width of the pelvis, giving her a characteristic gait. The vocal organs exhibit differences, which account for the difference in the voice. The chest and lungs are of smaller dimensions; the trachea is of less diameter; the larynx smaller; the

glottis shorter and narrower; and the cavities, communicating with the nose, of smaller size. This arrangement causes the voice to be weaker, softer, and more acute. The muscles and ligaments of the glottis are apparently more supple, so as to admit of the production of a greater number of tones, and to favour singing. The phenomena of expression, as we have often remarked, keep pace with the condition of the intellectual and moral faculties, and with the susceptibility of the nervous system. As this last is generally great in the female, the language of the passions, especially of the softer kind, are more marked in her.

The functions of nutrition present, also, some peculiarities. With regard to digestion, less food is generally required; the stomach is less ample; the liver smaller; and frequently,—at least more frequently than in the male,—the dentes sapientiæ do not appear. The desire for food at the stated periods is not so powerful; and it is generally for light and agreeable articles of diet rather than for the very nutritious; but the appetite returns more frequently, and is more fastidious, owing to the greater sensibility of the digestive apparatus. This, however, is greatly an affair of habit, and we have more instances of prolonged abstinence in her than in the male. The circulation is generally more rapid, the pulse less full, but quicker. Of the secretions, that of the fat alone requires mention, which is usually more abundant, and the product firmer. The cutaneous transpiration is less active, and the humour has a more acidulous odour. The urine is said, by some, to be less abundant, and less charged with salts; whence, it is asserted, there is not so great a disposition to calculous affections. So far, however, as we have had an opportunity for judging, it is secreted in greater quantity; and this may partly account for its seeming to have a smaller quantity of salts in any given amount; but the truth is, the freedom of the female from calculous affections is greatly owing to the shortness and size of the urethra, which admits the calculus to be discharged with comparative facility; and it is a common observation, that where the males of a family, hereditarily predisposed to gout, owing to their greater exposure to the exciting causes, become affected with that disease, the females may be subject to calculous disorders,—the two affections appearing to be, in some respects, congenerous. For the reasons already mentioned, stone rarely forms in the bladder of the female, and the operation of lithotomy is scarcely ever necessary. The desire to evacuate the contents of the bladder occurs more frequently in her,—probably, in part, owing to habit; and, in part, to the greater mobility of the nervous system.

In addition to these differences as regards the secretions, the female has one peculiar to herself,—menstruation,—a function which has already engaged attention. In the progress of life, too, the glandular system undergoes evolutions which render it especially liable to disease. About the period of the cessation of the menses,—sooner or later,—the mammæ frequently take upon themselves a diseased action, and become scirrhous and cancerous so as to require the organs to be extirpated.

In the treatment of disease, these sexual peculiarities have to be borne in mind. Owing to the greater mobility of the nervous system in the female, she usually requires a much smaller dose of any active

medicine than the male; and during the period when the sexual functions are particularly modified, as during menstruation, gestation, and the child-bed state, she becomes liable to various affections, some of which have ben referred to elsewhere; others belong more appropriately to works on pathology, therapeutics, or obstetrics.

b. *Acquired Differences.*

The acquired differences, observed amongst individuals, are extremely numerous. The effect of climate on the physical and mental characteristics is strikingly exhibited. The temperate zone appears to be best adapted for the full developement of man, and it is there, that the greatest ornaments of mankind have flourished, and that science and art have bloomed in exuberance; whilst in the hot, enervating regions of the torrid zone, the physical and moral energies are prostrated; and the European or Anglo-American, who has entered them full of life and spirits, has left them after a few years' sojourn, listless and shorn of his proudest characteristics. Nor is the hyperborean region more favourable to mental and corporeal developement;—the sensibility being blunted by the rigour of the climate. The effect of locality is, perhaps, most signally exemplified in the *Crétin* and the *Goîtreux*, of the Valais, and of the countries at the base of lofty mountains in every part of the globe; as well as in the inhabitants of our low countries, who are constantly exposed to malarious exhalations, and bear the sallow imprint on the countenance.

Not less effective in modifying the character of individuals is the influence of way of life, education, profession, government, &c. The difference between the cultivated and the uncultivated; between the humble mechanic, who works at the anvil or the lathe, and him whose avocation, like that of the lawyer and physician, consists in a perpetual exercise of the organ of intellect; and between the debased subject of a tyrannical government, and the independent citizen of a free state,—

> "Lord of the lion heart and eagle eye,"

is signal and impressive.

1. *Habit.*

To acquired differences from extraneous or intrinsic causes we must refer *habit*, which has been defined,—an acquired disposition in the living body, that has become permanent, and as imperious as any of the primitive dispositions. It is a peculiar state or disposition of the mind, induced by the frequent repetition of the same act. Custom and habit are frequently used synonymously; but they are distinct. Custom is the frequent repetition of the same act; habit is the effect of such repetition. By custom we dine at the same hour every day; the artificial appetite induced is the effect of habit.

The functions of the frame are variously modified by this disposition,—being, at times, greatly developed in energy and rapidity; at others, largely diminished. If a function be over and over again exerted to the utmost extent of which it is capable, both as regards energy and activity, it becomes more and more easy of execution; the organ is daily better adapted for its production, and is so habituated

to it, that it becomes a real want—a *second nature*. It is in this way, that we accustom the organs of speech, locomotion, &c., to the exercise of their functions, until, ultimately, the most varied combinations of muscular movements of the tongue and limbs can be executed with surprising facility. If, on the contrary, the organs of any function possess unusual aptitude for accomplishing it, and we accustom ourselves to a minor degree of the same, we ultimately lose a part of the aptitude, and the organs become less inclined, and less adapted to produce it. By custom we may habituate ourselves to receive an unusually small quantity of nutriment into the stomach, so that at length it may become impracticable to digest more.

A similar effect occurs as regards the quantity of the special irritant, which we allow to impinge on any of the organs of sense. If we accustom them to be feebly impressed, yet sufficiently so for the performance of their functions, they become incapable of supporting a greater quantity of the special irritant without indicating suffering. The miner can see into the farthest depths of his excavations, when, to the eye of one, who has descended from the bright light of day, all seems enveloped in obscurity. In this case, the sensibility of the organ of sight is developed to such an extent, that if the individual be brought into even a feeble light, the impression is extremely painful. The nyctalope is precisely so situate. His nerves of sight are so irritable, that, although he can see well in the night, he is incapable of accurate discrimination by day. On the other hand, exposure to intense light renders the sensibility of the visual nerves so obtuse, that objects are not so readily perceived in obscurity. The hemeralope, who sees in the day and not in the night, and who is consequently the antitheton of the nyctalope, has the nervous system of vision unusually dull, and incapable of excitement by feeble impressions.

It may be laid down as a general principle, that if we gradually augment the stimulus applied to any organ of sense, it becomes less susceptible of appreciating minor degrees of the same irritant; so that, in this way, an augmented dose is progressively required to produce the same effect. This is daily exemplified by the use of tobacco,—either in the form of chewing, smoking, or snuffing, which becomes a confirmed habit, and can only be abandoned—without doing great violence to the feelings—by attention to the principle deduced from practice,—that by gradually following the opposite course to the one adopted in acquiring the habit—that is, by accustoming the nerve of sense to a progressive diminution in the dose of the stimulus—an opposite habit may be formed, and the evil, in this manner, be removed.

When, by habit, we acquire extreme facility in executing any function, it may be accomplished apparently without the direct agency of volition. This is peculiarly applicable to the voluntary motions. We have elsewhere shown, that, in this case, habit only communicates the facility, and that there is no natural sequence of motions, and, consequently, no reason,—as in executing a rapid musical movement,—why one movement of the fingers should follow rather than another, unless volition were the guiding power. A sensation, however, which at first excites a perceptible exertion of volition, will, in time, produce it and the correspondent action, without our being sensible of its in-

terference; and so rapid is this process, that we seem to will two ends or objects at the same time, although they are evidently, when examined, distinct operations. The musician is not sensible of his willing any one motion; yet with the most exquisite nicety he touches a particular part of the string of the violin, and executes a variety of the nicest and most complicated movements with the most delicate precision.

It is a common remark, that "habit blunts the feeling but improves the judgment." To a certain extent this is true; but feeling is not blunted unless the stimulant, which acts upon the organ of sense, is too powerful, and too frequently repeated. When moderately exercised, the effect of education, in perfecting all the senses, is strongly shown. Sensations, often repeated, cease to be noticed, not because they are not felt, but because they are not heeded; but if the attention be directed to the sensation, custom adds to the power of discrimination. Hence the sailor is able to detect the first appearance of a sail in the distant horizon, when it cannot be perceived by the landsman; and a similar kind of discrimination is attained by the due exercise of other senses. The greater power of discrimination is doubtless owing to improvement in the cerebral or percipient part of the visual apparatus; but we have no evidence, that the latter has its action necessarily blunted.

It has been presumed by some physiologists and metaphysicians, that the will, by custom and exercise, may acquire a power over certain functions of the body which were not originally subject to it; nay, some speculatists have gone farther, and affirmed, that all the involuntary functions were originally voluntary, and have become involuntary by habit. Stahl and the other animists, who regarded the soul as the formative and organizing agent in animals, asserted, that it excites the movements of the heart, and of the respiratory, digestive, and other nutritive organs, by habits so protracted and inveterate, and so naturalized within us, that these functions can be effected without the aid of the will, and without the slightest attention being paid to them. Respiration, according to them, is originally voluntary; but, by habit, has become spontaneous; so that there is no farther occasion to invoke volition. Respiration goes on night and day, when we are asleep as well as awake; and they regard, as a proof that the action was originally dependent upon free will, that we are still able to accelerate or retard it at pleasure. They cite, moreover, the case of Colonel Townshend, related in another part of this work,[1] to show, that the action of the heart is capable of being influenced by the will; as well as the fact that it is accelerated or retarded under the different passions.

MM. Condillac, Dutrochet, and De Lamarck,[2] again, fantastically assert, that the different instincts, observed to prevail so powerfully in animals, are mere products of an acquired power, transmitted through successive generations. The views of the last distinguished naturalist regarding the effect of habit on organization, which he considers to tend to greater and greater complication, are singular and fantastic.

[1] Vol. i. p. 403.

[2] Philosophie Zoologique, tom. i. p. 218; and tom. ii. p. 451, edit. 1830.

The organs of an animal have not, he maintains, given rise to its habits: on the contrary, its habits, mode of life, and those of its ancestors have, in the course of time, determined the shape of its body, the number and condition of its organs, and the faculties it enjoys. Thus, the otter, the beaver, the waterfowl, the turtle, and the frog were not made web-footed that they might swim; but their wants having attracted them to the water in search of prey, they stretched out their toes to strike the water, and move rapidly along its surface. By the repeated stretching of the toes the skin that united them at the base acquired a habit of extension; until, in the course of time, they became completely web-footed. The camelopard, again, was not gifted with a long flexible neck, because it was destined to live in the interior of Africa, where the soil is arid and devoid of herbage; but, being reduced by the nature of the country to support itself on the foliage of lofty trees, it contracted a habit of stretching itself up to reach the high boughs, until its forelegs became longer than the hinder, and its neck so elongated that it could raise its head to the height of twenty feet above the ground!

The objections to all these views are,—that the functions in question are as well performed during the first day of existence as at an after period, and are apparently as free from the exercise of volition. The heart beats through fœtal existence for months before the new being is ushered into the world; and when, if volition is exerted at all, it can only be so obscurely. The case of Colonel Townshend is strange—passing strange—but it is almost unique; and the power of suspending the heart's action was possessed by him a short time only prior to dissolution. All the functions in question must, indeed, be esteemed *natural*, and instinctive, inseparably allied to organization; and hence differing from the results of habit, which are always *acquired*.

The opinion of Bichat, on the other hand, was, that habit influences only the animal functions, and has no bearing on the organic or nutritive. But this is liable to objection. We have seen, under Digestion, that if a bird, essentially carnivorous in its nature, be restricted to vegetable food, the whole digestive apparatus is modified, and it becomes habituated to the new diet. We know, also, that where drains are established in any part of the body, they become, in time, so much a part of the normal condition, that they can only be checked with safety by degrees.[1]

In the administration of medicines, habit has always to be attended to. The continued use of a medicine generally diminishes its power:—hence the second dose of a cathartic ought to be larger than the first, if administered within a few days. Certain cathartics are found, however, to be exceptions to this. Cheltenham water and the different saline cathartics are so. The constitution, so far from becoming reconciled to lead by habit, is rendered more and more sensible to its irritation. Emetics, too, frequently act more powerfully by repetition. Dr. Cullen asserts, that he knew a person so accustomed to excite vomiting on himself, that the one-twentieth part of a grain of tartrate of antimony and potassa was sufficient to produce a convulsive action of the

[1] Adelon, in Dict. de Méd., x. 498; and Physiologie de l'Homme, edit. cit., iv. 525.

parts concerned in vomiting. As a general rule, however, medicines lose their effect by habit, and this is particularly the case with tonics; but if another tonic be substituted for a day or two, and the former be resumed, it will produce all its previous effects.

2. *Association.*

Association, employed abstractedly, is a principle of the animal economy nearly allied to habit. When two or more impressions have been made upon the nervous system, and repeated for a certain number of times, they may become associated; and if one of them only be made, it will call up the idea of the other. It is a principle, which is largely invoked by the metaphysician, and by which he explains many interesting phenomena of the human mind, especially those connected with our ideas of beauty, or the contrary; our likes and dislikes, and our sense of moral propriety. Dr. Darwin[1] employed it to explain many complicated functions of the economy; and laid it down as a law, that all animal motions, which have occurred at the same time or in immediate succession, become so associated, that when one of them is reproduced, the other has a tendency to accompany or succeed it. The principle has, doubtless, great agency in the production of many of the physical, as well as psychical, phenomena; but its influence has been overrated; and many of the consecutive and simultaneous actions, to which we have referred under the head of Correlation of Functions, take place apparently as well the first time they are exerted as subsequently. Sucking and deglutition are good cases of the kind. Soon after birth, the muscles of the lips, cheeks, and tongue are contracted to embrace the nipple, and to diminish the pressure in the interior of the mouth; and, as soon as the milk has flowed to the necessary extent into the mouth, certain voluntary muscles are contracted. These propel the milk into the pharynx, where its farther progress is effected by muscles, *associated* or connected functionally, but not in the sense we are now employing the epithet; for here one action could not suggest another, according to the definition we have given of *association*, which requires that the acts should have been executed previously. Many of the cases, in fact, ascribed by Messrs. Darwin and Hartley[2] to the agency of this principle, are instinctive actions, in which a correlation—as in the case of deglutition—exists, but without our being able to explain the nature of such correlation, any more than we can explain other complicated actions and connections of the nervous system, of which this is doubtless one. Some of the most obstinate diseases are kept up by habit, or by accustomed associated motions; and, frequently, the disease seems to continue from this cause alone. Whenever intermittent fever, epilepsy, asthma, chorea, &c., have been long established, the difficulty of removing the influence of habit, or the tendency to recurrence, is extreme. In such cases, the principle of revulsion can be invoked with much advantage by the therapeutist.

[1] Zoonomia, i. 49, Lond., 1794.

[2] On man, i. 102, Lond., 1791.

3. *Imitation.*

The principle of imitation falls appropriately under this section. It may be defined,—that consent of parts, depending on similar organization, which, under the influence of the brain, enables them to execute acts similar to those executed by the same parts in another individual. Imitation, consequently, requires the action of the brain; and differs from those actions that are natural or instinctive to organs. For example, speech requires the action of imitation; whilst the ordinary voice or cry is effected by the new-born, and by the idiot, who are incapable of all observation, and consequently of imitation. The mode in which speech is acquired offers us one of the best examples of this imitative principle—if we may so term it. At a very early period, the child hears the sounds addressed to it, and soon attaches ideas to them. It discovers, moreover, that it is capable of producing similar sounds with its own larynx, and that these sounds are understood, and inservient to the gratification of its wants; and, in this way, speech, as we have elsewhere seen, is acquired. The difficulty is to understand in what manner this singular consent is produced. Sir Gilbert Blane has properly remarked, that the imitation of gestures is, at first sight, less unaccountable than that of sounds; as they are performed by organs that are objects of sight, and would seem therefore to be more readily transferable to corresponding organs of another person; but he probably errs, when, farther on, he remarks, that when children begin to articulate, they first attempt those letters, in the pronunciation of which the motions of the organs are the objects of sight; such as the *p* and *b*, among consonants, and the broad *a*, among the vowels, "giving occasion to a well-known etymology, from the infantile syllables, expressive of father and mother in all languages." We do not think, that this explanation is happy; and have elsewhere attempted to show, that the combination of letters, and the words referred to, are first enunciated, because they are the easiest of all combinations; and that the expressions *mamma*, *papa*, &c., are employed long before the child has acquired the power of imitation, and prior to its attaching the meaning to the words which it is subsequently taught to adopt. It is certainly singular how the child can learn to imitate sounds, where the action of the organs concerned is completely concealed from view. The only possible way of explaining it is to presume, that it makes repeated attempts with its vocal apparatus to produce the same sound it hears; and that it recollects the sensation produced by the contraction of the muscles when it succeeds; so as to enable it to repeat the muscular action and the sensation at pleasure. This is, however, a case in which volition is actively exerted. We have others, where the action occurs in spite of the individual, as in yawning. We see it in a second person, and, notwithstanding all our attempts to the contrary, the respiratory organs are excited through the brain, and we accomplish the same act. Nay, even thinking of the action will be sufficient to arouse it. Of a like nature to this is the sympathetic contraction of the uterus, which comes on, when a pregnant female is in the lying-in chamber during the accouchement of another, and to which we have referred under the head of Sympathy. Many morbid

phenomena are excited in a similar manner:—of these, squinting and stammering are familiar examples. Of 321 cases of squinting, of which the exciting causes were investigated, 61 were found to have been produced by imitation.[1]

4. VARIETIES OF MANKIND.

To determine the number of varieties, into which the great human family may be divided, is a subject considered to belong so completely to the naturalist, that we shall pass it over with a brief inquiry.

If we cast our eye over the globe, although we may find, that mankind agree in their general form and organization, there are many points in which they differ materially from each other. "With those forms, proportions, and colours, which we consider so beautiful in the fine figures of Greece,"—to use the language of Mr. Lawrence,[2]—"contrast the woolly hair, flat nose, thick lips, the retreating forehead, advancing jaws, and black skin of the negro; or the broad, square face; narrow oblique eyes; beardless chin; coarse, straight hair, and olive colour of the Calmuck. Compare the ruddy and sanguine European with the jet black African, the red man of America, the yellow Mongolian, or the brown South-Sea Islander; the gigantic Patagonian to the dwarfish Laplander; the highly civilized nations of Europe, so conspicuous in arts, science, literature, in all that can strengthen and adorn society, or exalt and dignify human nature, to a troop of naked, shivering, and starved New Hollanders, a horde of filthy Hottentots, or the whole of the more or less barbarous tribes, that cover nearly the entire continent of Africa;—and although we must refer them all to the same species, they differ so remarkably from each other as to admit of being classed in a certain number of great varieties; but with regard to the precise number, naturalists have differed materially."

Under the idea, that mankind are descended from one original pair, whatever changes have been impressed upon mankind can, of course, apply only to the descendants of Noah. The broad distinctions we now meet with could scarcely have existed in his immediate family, saved with him at the time of the deluge. They must necessarily have been of the same race. None of our investigations on this subject can, consequently, be carried back into antediluvian periods. Hence, the region, on which the ark rested, must be looked upon as the cradle of mankind. The question of the original residence of man has frequently engaged the attention of the philologist. It is one, which could be answered positively by the historian only, but unfortunately, the evidence we possess of an historical character is scanty in the extreme; and the few remarks in the sacred volume are insufficient to lead us to any definite conclusion. As far back as the date of the most remote of our historical records,—which extend to about two thousand years prior to the Christian era,—we find the whole of Asia and a part of Africa,—probably a large part,—peopled by different nations, of various manners, religion, and language; carrying on extensive wars with each other; with here and there, civilized states, possessing important

[1] Med. Examiner, July 10, 1841, p. 439.
[2] Lectures on Comparative Anatomy, Physiology, Zoology, and the Natural History of Man, 9th edit., p. 165, London, 1844.

inventions of all kinds, which must have required a length of time for discovery, improvement, and diffusion. After the subsidence of the deluge, the waters would first recede from the tops of the highest mountains, which would thus be the earliest habitable; and, in such a situation, the family of Noah—it has been conceived—increased, and thence spread abroad on the gradual recession of the waters. The earliest habitable spot was perhaps the elevated region of middle Asia, not the summits, which would be unsuitable, in every respect, for human existence; but some of the lofty plains, such as that of which the well-known desert Kobi or Schamo forms the highest point, and whence Asia sinks gradually towards the four quarters, and the great mountain chains proceed that intersect Asia in every direction. This has been suggested by Herder[1] and Adelung[2] as the cradle of the human race. In the declivities of this elevated region, and of its mountain chains, all the great rivers arise that flow on every side through that division of the globe. After the deluge, it would therefore soon become dry and project, like an extensive island, above the flood. The cold and barren elevation of Kobi would not itself have been well adapted for the continued residence of our second parents, but immediately on its southern side lies the remarkable country of Thibet, separated by lofty ridges from the rest of the world, and containing within itself every variety of climate. Although on the snow-capped summits the severest cold perpetually prevails, summer eternally reigns in the valleys and well-watered plains. The rice, too, the vine, pulse, and a variety of other productions of the vegetable kingdom, which man employs for his nutrition, are indigenous there; and those animals are found in a wild state which man has domesticated and taken along with him over the earth;—the ox, horse, ass, sheep, goat, camel, swine, dog, cat, and even the reindeer,—his only friend and companion in the icy deserts of polar regions. Zimmermann,[3] indeed, asserts, that every one of the domesticated animals is originally from Asia. Close to Thibet, and immediately on the declivity of this great central elevation, is the charming region of Kaschemire, the lofty site of which tempers the southern heat into a protracted spring.

The probabilities in favour of the cradle of mankind having been situate to the south of the elevated region of middle Asia are considered to be strengthened by the circumstance of the nations in the vicinity possessing a rude, meagre, and imperfect language, such as might be imagined to have existed in the infancy of the human intellect and of the world. Not less than two hundred millions of people are found there, whose language appears to be nearly as simple as it must have been soon after its formation. Kaschemire, by reason of the incessant changes it has experienced in ancient and modern times, has kept pace with the rest of the world in the improvement of its language; but not so, apparently, Thibet—its neighbour—and China, and the kingdoms of Ava, Pegu, Siam, Tunkin, and Cochinchina. All these extensive countries, and these alone in the known world, accord-

[1] Ideen zur Philosophie der Geschichte der Menschheit, Riga und Leipz., 1785–1792.

[2] Mithridates oder Allgemeine Sprachenkunde, Berlin, 1806–1817, Erster Theil, Einleitung.

[3] Geograph. Geschichte der Menschen, u. s. w., Leipz., 1778.

ing to Adelung, betray the imperfection of a newly-formed or primitive language. As the earliest attempt of the child is a stammering of monosyllabic tones, so,—says that eminent philologist,—must have been that of the original child of nature; and, accordingly, the Thibetans, the Chinese, and their two neighbours to the south continue to stammer monosyllabically, as they must have done thousands of years ago, in the infancy of their race. "No separation of ideas into certain classes, whence arose the parts of speech in cultivated languages. The same sound, which denotes *joyful*, signifies *joy* and to *gladden*, and this in every person, number, and tense. No art, connexion, or subordinate ideas are united to the rude, monosyllabic root, thereby communicating richness, clearness, and euphony to their meagre tongue. The rude, monosyllabic, radical ideas are placed, perhaps broken, and detached from each other, the hearer being left to supply the intermediate ideas. As the monosyllable admits of no inflection, the speaker either makes no distinction between cases and numbers, or he seeks for aid, in cases of great necessity, in circumlocution. The plural he forms, like the child, either by repetition,—*tree*, *tree*,—or by the addition of the words *much* or *more*, as *tree much*, *tree more*. *I much*, or *I more* is the same to him as *we*." From these and other circumstances, Adelung infers, that monosyllabic languages are primitive and the honourable ancestors of all others; but the argument is more plausible perhaps than sound. It has been correctly remarked by the author's distinguished friend, the late Mr. Duponceau, that, in all languages, there is a strong tendency to preserve their original structure, and from the most remote period, to which the memory of man can reach, a monosyllabic language has never been known to become polysyllabic, or conversely. Adelung farther infers, that the immediate descendants of Noah originally occupied the favoured region which he has described, and as population increased spread into the neighbouring districts, selecting, by preference, the near and charming countries of the south, east, and west. Hence we find, in those immediately bordering on Thibet, the earliest formed states, and the oldest civilization. History refers us to the East for the primordial germs of most of our ideas, arts, and sciences, whence they subsequently spread to the countries farther to the West, to Media, Persia, and western Asia.[1]

1. *Division of the Races.*

It is probable, that from western Asia, the sons of Noah,—Shem, Ham, and Japheth,—branched off in various directions, so as to constitute the three distinct stocks that divided the old world from time immemorial. These three are—1, the *White*, *Caucasian*, *Arabico-European*, or *European;* 2, the *Olive*, *Mongolian*, *Chinese*, *Kalmuck* or *Asiatic;* and 3, the *Negro*, *Ethiopian*, *African*, *Hottentot*, &c., each of

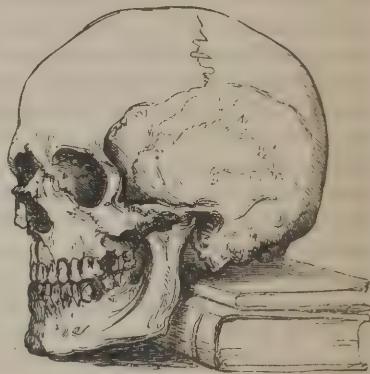
[1] In the Virginia Literary Museum, published at the University of Virginia in the year 1830, the author wrote a few popular papers, mainly with the view of attracting attention to the value of philological investigations in elucidating the history of nations; and of late, more especially, they have been invoked with eminent advantage in ethnological inquiries. See, in particular, the works of Adelung and Prichard. Also, Latham, The Natural History of the Varieties of Man, London, 1850; Man and his Migrations, Amer. edit., New York, 1852; and his Treatise on the Varieties of the Human Species, in Orr's Circle of the Sciences, vol. i. p. 305, London, 1854.

which has its own principal habitat;—the white being found chiefly in Europe and Asia Minor, Arabia, Persia, and India as far as the Ganges, and in north Africa; the Mongol occupying the rest of Asia, and having its focus on the plateaux of Great Tartary and Thibet; and the negro race covering almost the whole of Africa, and some of the Isles of New Guinea, the country of the Papuas, &c. The white or Caucasian variety are supposed to be the descendents of Japheth ("*audax Japeti genus*," Horace); the Asiatic the descendants of Shem; whilst Ham is regarded as the parent of the African. These three

Fig. 526.

Caucasian Variety.

Fig. 527.



Oval Skull of a European.

races,—the *Caucasian*, *Negro*, and *Mongolian*,—are alone admitted by Cuvier.[1] Blumenbach,[2] whose classification will serve our purpose as well as any of the others to which reference will be made presently, admits five,—the *Caucasian*, *Ethiopian*, *Mongolian*, *American*, and *Malay*.

a. *Caucasian Race.*

The Caucasian race is chiefly distinguished by the elegant form of the head, which approximates a perfect oval. It is also remarkable for variations in the shades of the complexion and colour of the hair. From this variety the most civilized nations have sprung. The name *Caucasian* was given to it from the group of mountains between the Caspian and the Black Sea,—tradition seeming to refer the origin of this race to that part of Asia. Even at the present day, the peculiar characteristics of the race are found in the highest perfection amongst the people who dwell in the vicinity of Mount Caucasus,—the Georgians and Circassians,—who are esteemed the handsomest people of the

[1] Règne Animal.

[2] Handbuch der Naturgeschichte, § 52, Götting., 1791: and De Generis Humani Varietat. Nativ., Götting., 1777.

earth. Figure 526, is given by Blumenbach as a specimen of the Caucasian race, near the original residence whence the epithet is derived. It represents Jusuf Aguiah Efendi, formerly ambassador from the Porte to London.

The Caucasian race has been subdivided into several great nations or families:—1. The *Arabs*, comprising the Arabs of the desert or Bedouins, the Hebrews, Druses, and other inhabitants of Libanus, the Syrians, Chaldæans, Egyptians, Phœnicians, Abyssinians, Moors, &c. 2. The *Hindoos* on the European side of the Ganges;—as the inhabitants of Bengal, of the coasts of Coromandel and Malabar, the ancient Persians, &c. 3. The *Scythians* and *European Tartars*, comprising also the Circassians, Georgians, &c. 4. The *Kelts* or *Celts*, whose precise origin is unknown, but presumed to be Indian. The descendants of this race are the Gauls, Welsh, Rhætians, &c. &c.; and lastly, the *Goths*, the ancestors of the Germans, Dutch, Swedes, Danes, &c. Both the ancient Kelts and Goths would seem to have been xanthous or fair haired races; although the former have often been described as dark haired; but this is by no means the case with their descendants.[1]

That the time of the first peopling of the European countries must have been very remote is exhibited by the fact, that at the dawn of history, the whole of Europe, from the Don to the mouth of the Tagus, was filled with nations of various physical characters and languages, bearing striking marks of intermixture and modification. At this period, there were, in Europe, at least six great nations. 1st. The *Iberians* with the *Cantabri*, in Spain, a part of Gaul, and on the coasts of the Mediterranean as far as Italy. 2dly. The *Kelts*, in Gaul, in the British Isles, between the Danube and the Alps, and in a part of Italy. 3dly. The *Germani* or *Goths*, between the Rhine, Danube, and Vistula. 4thly. The *Thracians*, with the *Illyrians*, in the southeast of Europe, and in western Asia. 5thly. The *Sclavi* in the north;—and 6thly. The *Fins* in the northeast. It is not improbable, that these different races migrated from Asia in the above order;—such at least is the theory of certain historians and philologers, and there is some reason for adopting it. They who migrated first would probably extend their wanderings until they were arrested by some invincible obstacle, or until the arrival of fresh tribes would drive them onwards farther and farther towards the west. In this way, they would ultimately reach the ocean, which would effectually arrest their farther progress, unless towards the south and north. The descendants of the ancient Iberians do now actually occupy the west of Spain,—the residence probably of their forefathers. Nearly about the same time, perhaps, as the Iberians undertook their migration, the Kelts, a populous tribe, migrated from some part of Asia, and occupied a considerable portion of middle Europe. To these succeeded the Goths, to the north, and the Thracians to the south; whilst the Sclavi, the last of the Asiatic emigrants, wandered still farther north. It is not easy to determine the precise link occupied by the Fins in this vast chain of nations. They were first known to history as a peculiar people in the north of Europe; but whence they proceeded, or whether they occupied their position to the north of the

[1] Prichard, Natural History of Man, p. 195, Lond., 1843.

Germani from choice, or were urged onwards by their more powerful neighbours, we know not. So long as there was sufficient space for the nations to occupy, without disturbing the possessions of their neighbours, they probably kept themselves distinct; but as soon as the land was filled, a contest arose for the possession of more extensive or more eligible regions; wars were, consequently, undertaken, and the weaker gradually yielded their possessions, or their sovereignty, to the stronger. Hence, at the very dawn of history, numerous nations were met with, amalgamated both in blood and language;—for example, the Kelto-Iberians of Spain; the Belgæ or Kymbri of Gaul and Britain; the Latins, and other nations of Italy, and probably many, whose manners, characters, and language had become so melted into each other as to leave little or no trace of the original constituents. The Letti, Wallachians, Hungarians, and Albanians of eastern Europe, are supposed to afford examples of such amalgamation, whilst the mighty Sclavonic nation has swallowed up numbers of less powerful tribes, and annihilated even their names forever. This it is, which frequently embarrasses the philological historian; and prevents him, without other evidence, from deducing with accuracy the parent stocks, or the most important components in ethnical admixtures. Dr. Morton, in his splendid and valuable contribution to the Natural History of Man,[1] subdivides the Caucasian race into seven families:—the Caucasian, Germanic, Celtic, Arabian, Libyan, Nilotic, and Indostanic.

b. *Ethiopian Race.*

The *Negro*, *African*, *Ethiopian*, *Black man* of Gmelin, occupies a less extensive surface of the globe, embracing the country of Africa which extends from the southern side of Mount Atlas to the Cape of Good Hope. This race is of a less perfect organization than the last,

Fig. 528.

Negro Skull.

and has some characteristics, which approximate it more to the monkey kind. The forehead is flattened and retiring; the skull smaller, and

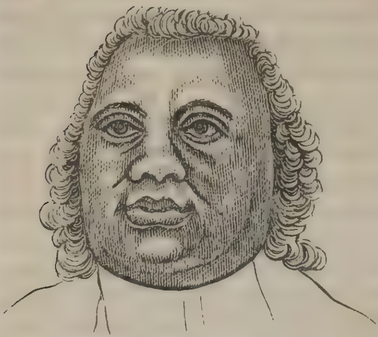
[1] Crania Americana, p. 5, Philad., 1839.

of less capacity than that of the European. On the other hand, the face, which contains the organs of the senses, is more developed, and projects more like a snout. The head is in other words *prognathous* or has the jaws prolonged or extended forward. The lips are large; the cheek bones prominent: the temporal fossæ hollower; the muscles of mastication stronger; and the facial angle smaller;—the head of the negro, in this respect, holding a middle place between the Caucasian and ourang-outang. The nose is expanded; the hair short and woolly, very black and frizzly. It has been considered by some to be wool, and not hair; and, therefore, a characteristic of the African races, and of some other dark-coloured tribes chiefly inhabiting tropical climates. A writer,[1] who embraces the former view, affirms, as the result of his microscopic observation, that the hair of the Choctaw and some other nations of American Indians is cylindrical; that of the white man oval; whilst "the wool of the negro is *eccentrically elliptical* or *flat*." But its woolly nature is not admitted by distinguished anthropological observers; as by Dr. Prichard;[2] and Dr. Carpenter[3] affirms, that "microscopic examination clearly demonstrates, that the hair of the negro has exactly the same structure with that of the European, and that it does not bear any resemblance to wool save in its crispness and tendency to curl." Dr. Neill[4] has drawn attention to the fact, that in the negro particularly, the condyloid processes of the occipital bone are divided by a transverse ridge or groove into two distinct articular surfaces, which are often in different planes; and farther, that the superior maxillary bone has a distinguishing mark. In the Caucasian head, there is a sharp ridge or crest continuous with the anterior edge of the nasal process, and reaching to the anterior nasal spine, which is wanting in the Ethiopian head,—the surface in it being flat and the orifice of the nose resembling that of the "monkey and other inferior mammalia." In the superior maxillary bone of the fœtus, the crest is equally wanting and the surface flat; so that "here again"—Dr. Neill remarks—"we see, that the adult African head permanently retains a form characteristic of the fœtal head, and that this form belongs to many inferior animals." The Ethiopian has, moreover, a less developement of the fingers, and therefore a greater length of web. The skin is black, but this colour is not characteristic of the race, for the Hottentots and Caffres are yellow.

The next figure is the head of J. J. E. Capitein, selected by Blumenbach as the representative of his race. He was an intelligent negro, and published several sermons and other works in Latin and Dutch. His portrait was taken by Van Dyk. This case of great intelligence in the negro is not common; but it exhibits what may be expected from him under favouring circumstances. In almost all situations in which he is found, it is in a state of slavery and degradation, and no inference can be deduced regarding his original G r u n d k r a f t—as the

[1] P. A. Browne, The Classification of Mankind by the Hair and Wool of their Heads, p. 4, Philadelphia, 1850; and Trichologia Mammalium, p. 51, Philad., 1853.
[2] Op. cit., p. 103.
[3] Principles of Human Physiology, Amer. edit., p. 827, Philad., 1855. Also, Art. Varieties of Mankind, Cyclop. of Anat. and Physiol., iv. 1338, Lond., 1852.
[4] Amer. Journ. of the Medical Sciences, Jan., 1850, p. 78.

Fig. 529.

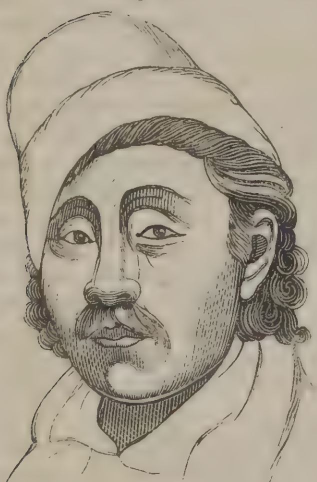


Ethiopian Variety.

Germans call it—or fundamental power. Hayti has afforded numerous examples of the sound judgment, and even distinguished ability with which her sable inhabitants are capable of conducting not only the municipal, but foreign concerns of a considerable community. It must be admitted, however, that from organization, this race would seem to be, *cæteris paribus*, less fitted for intellectual distinction than the Caucasian,[1] and singular differences have been observed between the two, when exposed to similar mental and physical influences.[2] The Ethiopian race is subdivided by Dr. Morton[3] into six families:—the Negro, Caffrarian, Hottentot, Oceanic Negro, Australian, and Alforian.[4]

c. *Mongolian Race.*

Fig. 530.



Mongolian Variety.

The *Mongolian*, *Asiatic*, *Kalmuck*, *Chinese* race, *Brown man* of Gmelin, is recognized by prominent wide cheek bones; flat, square visage; small, oblique eyes; straight black hair; scanty beard, and olive complexion. The marginal head is from Blumenbach. It is that of Feodor Ivanowitsch, a Kalmuck given by the Empress of Russia to the hereditary Princess of Baden. He was educated at Carlsruhe, and was a most distinguished painter at Rome. The portrait was sketched by Feodor himself.

The Mongols are spread over the central and eastern parts of Asia, with the exception of the peninsula of Malacca. They likewise stretch along the whole of the Arctic regions, from Russia and Lapland to Greenland, and the Northern parts of the American continent, as far

[1] See vol. ii. p. 175.

[2] See abstract of a memoir by Dr. B. H. Coates, "On the effects of secluded and gloomy imprisonment on individuals of the African variety of mankind in the production of disease," in Proceedings of the Amer. Philosoph. Soc., vol. iii. p. 143, Philad., 1843; also a paper by M. Boudin on the Comparative Pathology of the different races of Man, in Annales d'Hygiène, xlii. 38–80, cited in British and Foreign Medico-Chirurgical Review, Oct., 1849, p. 551; and the Report of a Committee, of which Dr. Isaac Parrish was Chairman, on the effects of confinement in prisons and penitentiaries, &c. &c., on the health of their inmates, in Transactions of the American Medical Association, vol. 2, Philad., 1849.

[3] Op. citat., p. 7.

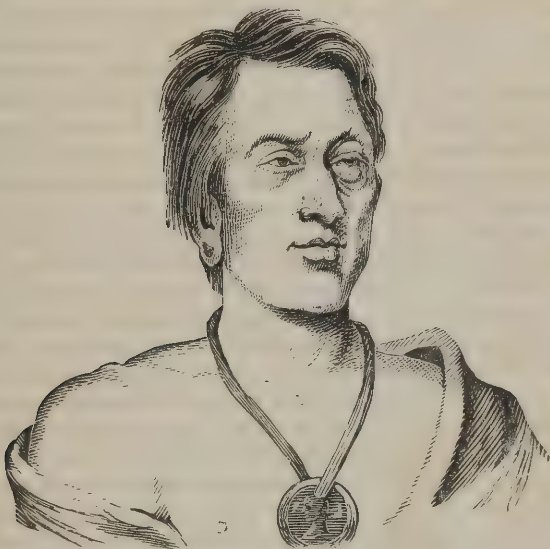
[4] The Alfores or Horaforas are considered aboriginal in many islands of the Indian Archipelago. They are most numerous in New Guinea, the Moluccas, the Magindano:

as Behring's Straits,—the Laplanders and Esquimaux being evidently of the same race as the Koriaks, Kamtschadales, Japanese, &c., of the Asiatic continent. Dr. Morton includes in this race five families:—the Mongol-Tartar; Turkish; Chinese; Indo-Chinese, and Polar.

d. *American Race.*

The *American race, Red man* of Gmelin, or more properly *brown man*, differs greatly in stature, colour, and physiognomy in various parts of the continent; but his medium height corresponds with that

Fig. 531.



American Variety.

of the European. His colour is from a cinnamon-brown to a deep copper. The hair is almost always black, straight, and stiff. The features are large and strongly marked, except the eyes, which are commonly deep-seated, or sunk in large sockets. The forehead is generally low, somewhat compressed at the sides, and slightly retreating. Facial angle about 80°. Nose generally considerably raised from the face, sometimes arched; cheek bones high, and widely separated; angle of the jaw broad, and chin square. The accompanying head is that of Ongpatonga, (*Big Elk*,) chief of the Omawhaw Indians.[1] Dr. Morton divides the American race into two families;—the American and Toltecan;—the latter embracing the civilized nations of Mexico, Peru, and Bogota.[2]

in Celebes they are said to be sometimes as fair as the Malays, and the savage Dyaks of Borneo appear to belong to the same family. Dr. Morton thinks it not improbable, as suggested by Dr. Prichard, that the Alfores are but a branch of the Australian stock.—Crania Americana, p. 95.

[1] Godman's American Natural History, Philad., 1826–1828.

[2] Crania Americana, p. 83, Philad., 1839.

e. *Malay Race.*

The *Malay* or *Australian race*, *Tawny man* of Gmelin, is admitted by many naturalists, owing to the difficulty of referring it either to the Caucasian Indian, or the Chinese Mongolian in its vicinity. This Malay variety extends from Malacca to the most remote islands of the great Indian and Pacific Ocean, from Madagascar to the Maldives inclusive; inhabits Sumatra, Java, Borneo, Celebes, and adjacent islands; the Molucca, Ladrone, Philippine, Marian, and Caroline groups; New Holland, Van Diemen's Land, New Guinea, New Zealand, and the various islands scattered through the South Sea. It is termed *Malay*, because supposed to have proceeded originally from the Peninsula of Malacca, and to have spread thence over the adjacent islands,—a supposition, which is not confirmed by history: on the contrary, according to Mr. Marsden, it is clearly demonstrated, that the Malays went from Sumatra to Malacca in the twelfth century. No well-marked common characters can be assigned to this variety; for, under the term *Malay*, races are included, which seem to differ materially from each other; so much so, indeed, as to induce many naturalists to refuse the admission of the Malay as a distinct variety. Their colour may be said to be brown, in various shades, from a light tawny to almost black: the forehead is low and round; the nose full and broad; nostrils wide; mouth large; hair thick, crisp, and always black, as well as the iris. Fig. 136 exhibits an individual of this race; it is the head of a New Zealand chief. Cuvier,[1] Rudolphi,[2] Virey, and others consider the Malay variety to be a mixture of the Mongol of Asia and the negro of Africa. Dr. Morton[3] divides the Malay race into two families—the Malay, and Polynesian.

In New Guinea, and the small islands around, the *Papuas* are found, who resemble the negroes still more strongly; and similar races are met with in the Archipelago of the Holy Ghost, and in the isles of Andaman and Formosa. They are presumed to belong really to the negro race, and to have descended perhaps from individuals of that variety, who have wandered, or been driven, from their original settlements. Some of them resemble the Guinea negro in every particular.

Since the work of Blumenbach was issued, many other races have been added to those admitted by him; especially by Virey,[4] Desmoulins,[5] Malte-Brun,[6] Bory de Saint-Vincent,[7] Gerdy,[8] Broc,[9] and Pickering,[10] who,—like their predecessors,—dissatisfied with the divisions that had been adopted by naturalists, have taken colour as the

[1] Op. cit.

[2] Grundriss der Physiologie, th. 1, Berlin, 1821.

[3] Op. cit., p. 6.

[4] Histoire Naturelle du Genre Humain., 2de édit., Paris, 1824.

[5] Hist. Naturelle des Races Humaines, Paris, 1826.

[6] Géographie Universelle, Paris, 1816.

[7] L'Homme, Essai Zoologique sur le Genre Humain., 2de édit., Paris, 1827.

[8] Physiologie Médicale, tom. i.

[9] Essai sur les Races Humaines, p. 25, Paris, 1836.

[10] United States Exploring Expedition, during the years 1838, 1839, 1840, 1841, 1842, under the command of Charles Wilkes, U. S. N., Philad., 1845. The Races of Man and their Geographical Distribution, by Charles Pickering, M. D., &c., Boston and London, 1848.

basis of theirs. For *race* they substitute *sub-genus;* of which they admit four,—the *white*, *yellow*, *negro* or *black*, and *red*.

The various classifications exhibit the vacillation that yet exists regarding the precise number of races which should be admitted. Every division must necessarily be arbitrary, and the individuals composing each variety be far from alike. We find the greatest diversity, for example, amongst the nations of the Caucasian variety, and even amongst any of its subdivisions. The Frenchman can be distinguished from the German, the Spaniard from the English, &c., and if we were to push the system of subdividing, which appears at present to be fashionable, we might constitute almost every nation of the globe into a distinct variety.

2. *Origin of the Different Races.*

It has been an oft agitated question, whether all the varieties amongst mankind must be regarded as belonging to the same species,—the differences which we observe being referable to extraneous circumstances acting through a long succession of ages; or whether they must not be regarded as distinct species *ab origine.* By many, the discussion of the subject has been esteemed not only unnecessary but profane, inasmuch as the sacred historian has unequivocally declared, that all mankind had a common origin. Such a declaration, however, is not so clear as has been argued; for the sacred writings inform us, that Cain sought his wife in another land—and therefore, it might be presumed, in one not belonging to his own immediate family.[1] We have already remarked, however, that in accordance with biblical history this can scarcely be a question, that concerns our first parents; but belongs exclusively to the family of Noah; for, in his descendants, all these varieties must have occurred. From the part of Asia, previously described, his immediate descendants must have spread abroad to the north and south, the east and west,—Europe being peopled by the migratory hordes, which proceeded towards the north-west; and Africa by those from southwestern Asia. These migrations may have taken place by land, except in the case of our own continent, where a slight sea-voyage, of not more than thirty-nine miles, across Behring's Straits, even in frail vessels, would be sufficient to transport emigrants without much risk of misadventure; and even this short voyage would be rendered unnecessary during the winter season, the strait being solidified into a continuous mass of ice. Europe probably received its inhabitants long before navigation existed to any extent. Subsequently, when a coasting trade was first established,—to which the enterprise of nations would necessarily be limited in the first instance, until by improved vessels and a better system of management, they were enabled to brave the terrors of the ocean, and undertake their adventurous voyages of discovery,—many of the coasts, especially of the Mediterranean, received swarms of emigrants, a circumstance, which accounts for the motley population, observable, at an early period, in these regions. Carthage, we know, was settled by the Phœnicians; and southern Italy

[1] See, on this subject, a well-written and elaborate work, entitled "An Investigation of the Theories of the Natural History of Man, by Lawrence, Prichard, and others," &c. &c., by William Frederick Van Amringe, New York, 1848.

and Spain, in this manner, received their Greek colonies. Dr. Copland[1] has even expressed his belief in the view, that this continent was visited "by Phœnician navigators, the greater part of whom settled in it, particularly in Mexico; and that the imperfect navigation of that era prevented many of the adventurers, if not all of them, from returning." The notion is, however, hypothetical.

The greatest difficulty has been,—to comprehend how the Caucasian and Ethiopian varieties could have originated from the same source. The other varieties of mankind, if we exclude the negro, could be referred, with less hesitancy, to the same primitive stock,—the changes being caused by adventitious circumstances operating for an immense period; but it has seemed to many naturalists impossible to suppose, that the characters of the negro could, by any process, become converted into those of the European, and conversely.

Under the view of the unity of the human race, it might be presumed, that the people of antediluvian times had but few physical differences, and constituted one large family, modified, perhaps, but not materially, by circumstances,—the two antithetical races, the white and the black, first arising in postdiluvian periods. If we adopt this view, the question regarding the difference of *species* between the white and black would require no agitation.[2] But how are we to explain the essential differences as to form and colour, which we notice amongst the nations of the earth?

In the infancy of anthropology, it was asserted, that the white races inhabit the cold and temperate regions of the earth, whilst the tawny and darker are situate under a more vertical sun. Within certain limits, the sun is doubtless possessed of the power of modifying colour. The difference between one, who has been for some time exposed to the rays of a tropical sun, and his brethren of the more temperate climates, is a matter of universal observation. The inhabitant of Spain is distinguishable from the French, German, English, &c.; and we can understand, why the Southern Asiatic and African women of the Arab race, when confined within the walls of the hareem, may be as white as the fairest Europeans. There are many exceptions, however, to the notion which has prevailed, that there is an exact ratio between the heat of the climate and the blackness of the skin. For example, at the extreme north of Europe, Asia, and America, we find the Laplanders, Samoiedes, Esquimaux, &c., with the skin brown, and the hair and iris black; whilst in the vicinity of the Laplanders, are the Fins, —a people of large stature compared with the Laplanders, with fair skins and bluish-gray eyes. In the same manner, to the south of the Greenlander,—of short stature, brown skin, and dark hair,—is the tall and fair Icelander. Many distinct tribes exist in the interior of Africa having a red or copper hue, with lank black hair, and in the midst of black varieties of the species. A similar fact was observed by Humboldt in different parts of South America. Again, the negro race is not always found in the torrid zone. On our own continent, none have ever been met with, except what have been imported; and these, after

[1] Notes to translation of Richerand's Physiology.

[2] See, on the subject of hybridity as a test of specific affiliation, the remarks at pages 461 & 472 of this volume.

repeated descents, have retained their original character; whilst, as we have seen, negroes are met with in Australia under a climate as cold as that of Washington. The fact of the slight mutation effected by ages on the character of a race is strikingly shown by the circumstance before referred to,—that in some of the monuments of Egypt, visited by Belzoni and Champollion, representations of the negro, presumed to be nearly four thousand years old, exhibit the features to be almost identical with those of the same race in the present day. The Jew affords an example of the same immutability, as well as the Esquimaux, who strikingly retains the evidence of his Kalmuck origin. Complexion, and, to a certain extent, figure are doubtless modified by climate, but the essential characters of the organization remain little if at all changed. Volney has fancifully supposed, that the elongated visage of the negro is owing to the wry face habitually made under exposure to the rays of the sun. Independently, however, of the objection, that this would be insufficient to account for the striking peculiarities of the negro head, it has already been remarked, that these peculiarities do not exist among other races inhabiting equally hot climes; and that the negro himself is not confined to those climes, and ought, consequently, to lose the *museau* or snout, when the country is so cool as to render the wry face or *moue* unnecessary. It may then, we think, be concluded, that the evidence in favour of the colour of the negro, the red man, or the tawny, being produced directly or indirectly by the solar rays, is insufficient to establish the point. One important argument in the negative is the fact, that in all cases the children are born fair, and would continue so, if not exposed to the degree of solar heat, which had produced the change in their progenitors.

In addition to the influences of temperature, and climate, that of food, and of different manners and customs has been frequently urged, but without any precise results being deduced. The effect of difference in manners and customs is shown in the results of domestication on animals—as in the case of the wild and the disciplined horse; and of the bison and the ox—which last is regarded as the bison in a state of tameness. The precise cause of such modification we know not. It is not confined to the animal; but is signally evidenced in the vegetable. The flower of the forest, when received into the *parterre* and carefully nurtured, may develope itself in such a manner as to be with difficulty recognisable. The change seems to be produced by variation of climate and nutrition, but in what precise manner we know not. The important modifying influence of locality on the developement of the moral and physical powers has been more than once referred to. Perhaps the most remarkable examples are met with at the base of lofty mountains, particularly of the Alps, and in some of the unhealthy districts of France especially. One of these is *cretinism*, a singular case of malformation, with which we are happily unacquainted in the United States. This is a state of idiocy, which is remarkable in its subjects being always more or less deformed, and in its appearing to originate from local influences. The *crétin* has every characteristic of the idiot; and, in addition, is often distinguished by a large *goître* or swelling of the thyroid gland; by soft flabby flesh; and by shrivelled, yellowish, or pale and cadaverous skin, covered, at times, with filthy cutaneous

eruptions. The tongue is thick and pendant; the eyelids large and projecting; the eyes gummy, red, and prominent; the nose flat; the mouth gaping and drivelling; the face puffy, and at times, violet-coloured, and the lower jaw elongated. In several, the forehead is broad inferiorly, and flattened and retreating above, giving the cranium the shape of a cone rounded towards its smaller extremity. The stature of the cretin is generally small, scarcely ever exceeding four feet and a few inches; the limbs are frequently malformed, and almost always kept in a state of flexion. All the cretins are not affected with goître. Some have large and short, whilst others have thin, and long necks. Like the idiot, the cretin does not generally live long, scarcely ever surviving his thirtieth year. It has been estimated,[1] that in the valleys of Switzerland, the number of cretins at the present day amounts to eight thousand, who are completely idiotic, and to double or treble the number, who are more or less defective intellectually.

Authors have differed in opinion as to the causes of this deplorable condition. It is observed almost exclusively in the deep and narrow valleys at the foot of lofty mountains, and in mountain gorges; and hence is common in that part of the Alps called the Valais or Wallais; in the valley of Aost, La Maurienne, &c. It is met with, too, at the foot of the mountains of Auvergne, the Pyrenees, the Tyrol, &c. De Saussure, Esquirol, Foderé, Rambuteau—and all who have had an opportunity of observing these miserable wrecks of humanity—believe, that the great cause is the concentrated, moist, and warm air, which prevails throughout almost the whole of the year in the valleys and mountain gorges where it is found to exist. That it is dependent upon locality is obvious, but how this acts we know no more than we do of the immediate cause of other endemic affections—intermittent fever, pellagra, beriberi, &c. &c.

Not long ago, two children were exhibited in the United States under the name of "Aztec children," and were announced as belonging to a race of dwarfs, the descendants of priests from a hitherto undiscovered city of Central America. The author had an opportunity of inspecting them, and was satisfied that they were casual dwarfs, intellectually and corporeally. According to Dr. J. M. Warren,[2] who examined them carefully, it is now pretty well understood, that they belong to some of the mixed tribes of Indians inhabiting Central America.

After all, perhaps, the strongest arguments in favour of extraneous circumstances occasioning, in the lapse of ages, the different varieties, which we observe in the great human family, are those derived from the changes that must have occurred amongst many of the inferior animals. The dog, in its wild state, has always pretty nearly the same characters,—being covered with hair of the same colour: the ears and tail, and limbs, have the same shape, and it exhibits, apparently, the same powers and instincts; but, on this matter, our knowledge, derived from observation, is necessarily limited. Yet what a number of varieties are observed in the animal when it becomes domesticated; and how

[1] British and Foreign Medical Review, April, 1844, p. 514.

[2] An account of two remarkable Indian dwarfs, exhibited in Boston under the name of Aztec Children. (From the Amer. Journ. of the Med. Sciences), Boston, 1851.

different from each other, in shape, colour, character of skin, and instincts, are the spaniel, hound, grayhound, pointer, mastiff, terrier, cur, pug, lapdog, &c.; differences certainly as great as between the varieties of mankind.[1] These differences, it is presumable, may have been produced partly by the occurrence of accidental varieties, affecting perhaps a whole litter,—male and female; so that if these again were to be coupled, the variety, thus accidentally caused, might become permanent. Such accidental varieties occasionally occur in the human species, but they are soon lost, in consequence of the wise law that prevents individuals, within certain degrees of consanguinity, from marrying. It is by no means uncommon, for example, for different children of the same family, from some accidental cause, to be born with six fingers. The author has met with two families in each of which more than one individual was thus circumstanced; and Sir Anthony Carlisle[2] has detailed the remarkable case of a family from this continent, where the superfluity extended, in the case of a female, to two thumbs on each hand, and to six toes on each foet. She married and had several children, who, in their turn, became parents, and transmitted the peculiarity to the children to the fourth generation. Now, if the members of this family had continued to marry in and in, a new race of individuals might have been perpetuated, possessing the unnecessary additions in question. Under existing laws and customs it must always happen, that where such peculiarity exists in one parent only, it must soon become extinct; yet, as we have seen, it may be pertinacious enough to persist for some generations. Fortunately, also, it happens, that, as a general rule, no change, which occurs accidentally in the parent after birth, is liable to be extended to the progeny. Were the rule other than it is, the most strange and innumerable varieties of races would arise. Where a limb had become distorted or amputated, a stock of one-limbed animals would be formed; the docked horse would propagate a mutilated colt; the operation of circumcision, performed on one parent, ought to be sufficient for the whole of his descendants, &c. &c.[3]

[1] Prichard's Natural History of Man, p. 53, Lond., 1843.

[2] Philosoph. Transact. for 1814.

[3] The last edition of this work contained the following note: "The author has been informed by one who has had ample opportunity for observation, that when two deaf and dumb individuals marry, the defect is rarely or never observed in their progeny; but that the contrary is the case with the born blind." Desirous of possessing accurate information on this subject as well as on the influence of intermarriages of near relations in the propagation of the defects in question, the author addressed a letter to Mr. Hutton, the able Superintendent of the Deaf and Dumb Institution, in Philadelphia, who kindly favoured him with the results of his long observation.

Deaf and Dumb Institution, Jan. 17, 1853.

Dear Sir: Your note was received yesterday afternoon, requesting the results of our experience, in regard to the marriage of near relations, in causing deafness in their progeny. Our attention has been drawn to the subject too recently, to have enabled us to gather a sufficient number of facts on which to rely for an inference. However, we have been struck with the considerable number of the parents of our pupils who have been first cousins, or more or less related by consanguinity.

Respecting the other question, as to the propagation of the infirmity by deaf mute parents, I would say, that from our experience, we have inferred that deaf mute parents are no more liable to have deaf mute children than other persons. We have heard of a number of marriages, where all the children could hear and speak with two or three

In addition to this mode of accounting for the great number of varieties in animals of the same species, the influence of difference in manners and customs, to which allusion has already been made, has

rare exceptions. We have, at present, a mute child of deaf-mute parents, but the cases are few. In Europe, it has been observed that the infirmity reappears in the third or fourth generation, and this seems to be partially confirmed by the observations of Hartford and New York.

I venture to mention a fact about the difference in the proportion between the sexes among the deaf-mutes. Dr. Peet, of New York, says, "that among the population at large, the males exceed the females in the ratio of about 25 to 24; but, among the deaf and dumb, the males are to the females nearly as five to four. Similar results have been presented by European enumerations. Among the blind and idiots, the disproportion of males is still greater, being as four to three; but, among the insane, the sexes are nearly equal."

I regret that I cannot give more definite and reliable answers to your queries, but remain, respectfully, Your friend and ob't servant,

A. B. Hutton.

Dr. Dunglison.

Since this letter was written, a full and valuable report has been made by Dr. Peet, President of the New York Institution for the Instruction of the Deaf and Dumb (*Twenty-Fifth Annual Report*, New York, 1854), in which he deduces, that if, in general, there is one child congenitally deaf, in this country, in 3,600, there will be, of the children of cousins, about one in 700; a result which "corresponds nearly enough to that made out for Ireland." In regard to the progeny of deaf mutes, he remarks: "It should be observed, that the marriages of deaf mutes have been rare till within a few years, and hence, that we are not yet provided with a sufficient number of facts, to warrant us in assigning positively the proportion of such marriages, in which the children may be expected to inherit the infirmity of their parents. We can, however, show, that it is much the most common for the children of deaf mute parents to possess the faculties of which their parents were deprived." On the whole subject of deaf dumbness, much interesting statistical information has been given by Mr. Wilde, of Dublin, in his *Practical Observations on Aural Surgery, &c.*, Amer. edit., Appendix, p. 412, Philad., 1853.

From Mr. Chapin, the Principal of the Pennsylvania Institution for the Instruction of the Blind, whose competent observation has extended—like that of Mr. Hutton—over a long series of years, and whose attention has been successfully directed to every subject connected with the blind, the author received the following reply to a similar letter addressed to him:—

Pa. Instit. for the Instruction of the Blind, Jan. 18, 1856.

Dear Sir: I take pleasure in answering your request, that I would furnish you such facts as have fallen under my observation, where blindness has been the evident result of intermarriage of near relatives, or by hereditary transmission from blind parents. I omit names, though these could be given:—

1. Two brothers (F.), Ohio, parents, first cousins.
2. J. M., a girl, " " "
3. M. P., " " " "
4. Two sisters (B.), and a half-blind, weak-minded brother—the offspring of an intermarriage between their *mother* and her *uncle*.
5. Two boys (B.), Ohio; parents, first cousins.
6. Four children (R.), one family, Ohio; parents, first cousins.
7. Four children (H.), three boys and a girl, Ohio; parents, cousins. This is a peculiar case. The parents and grandparents had perfect sight, but the mother had four *uncles and aunts* blind; and her brother, whose vision was good, had two blind children.
8. Two females. Their fathers (brothers) married two sisters, who were also their cousins; each had a blind daughter.
9. Two blind, and one idiotic child (H.), one family; parents, cousins.
10. Two blind boys (B.), whose father's *brother* has a blind daughter. I know not whether the mothers were otherwise related.
11. A family of *seven* children, blind; parents, cousins.
12. Three blind children—same family (T.); parents, cousins.
13. Two children (C.), mother blind. A note, respecting this family, says: "The

been brought forward; and it has been conceived, that the effect of civilization and refinement on the human race may be analogous to that of domestication on inferior animals. This kind of influence is said to be particularly observable amongst the inhabitants of Hindostan, where, in consequence of the division into castes, the same condition of life, and the same occupation are continued without change through many successive generations. The artisans, who are a superior class, are of manifestly lighter complexion than the tillers of the soil; and in many of the islands of Polynesia, the same difference exists between the classes as in Hindostan.

The believers, then, in the Mosaic account of the creation, and the deluge, must regard all the varieties of mankind to have descended from the same family,—that of Noah,—and the different changes, which have been impressed upon their descendants, to be results of extraneous influences acting through a long succession of ages, added to the production perhaps of accidental varieties, which may have occurred in the very infancy of postdiluvian existence, when the intermarriage

parents have a large family of children, and all (save now and then a rare exception) go blind between the ages of sixteen and twenty;" and of one of these (a young lady), it says: "She is of the *seventh generation*, nearly all of whom have been blind"—that is, one of the parents in each generation.

This is the only decided case of *hereditary* transmission of blindness in my knowledge, which extends to an experience of fifteen years, and with much observation directed to that particular point. While visiting the "Hospice des Quinze-Vingts," in Paris, I made particular inquiries as to the birth of blind children of blind parents. There were, at that time, 113 children, *one* or *both* of whose parents were blind. But *every child had perfect sight*. I further inquired of the Director, whether he had ever known a blind child born there. He said he *had not*—and his knowledge extended back twenty years. (See "Report on the Benevolent Institutions of Great Britain and Paris, &c.," by William Chapin, &c., p. xxiii., Columbus, 1846.)

These facts are important when we consider how little data we can have on such a subject; for marriages among the blind are very rare. I have been acquainted with the domestic history of several hundred blind persons in this country, and have known about twenty-five or thirty marriages, in which one of the parties was blind, but *never a blind offspring*. In two or three cases, both were blind. The children of two of these families have sight. Some statistics on blindness may be found in the *Twentieth Annual Report of the Managers of the Pennsylvania Institution for the Instruction of the Blind*, p. xxi., and elsewhere.

I have no doubt, other cases, if examined into, would show a larger number of instances in the same institutions, where the blindness has resulted from intermarriage of near relations. My inquiries have been more particularly confined to examples where two or more are found in the same family. I always suspect this cause, and it is more frequently so than otherwise.

Often *idiocy* is in the same family with blindness. But I have never, to my knowledge, found any *deaf mutes* in the same family with the blind. Yet, in my numerous inquiries in various Institutions for Deaf Mutes, as well as Blind, I have found intermarriages of those related to be a frequent cause of that privation also.

I have confined myself to *facts* rather than speculations, believing these are all you need. I am, very respectfully, dear sir, yours, &c.,

William Chapin.

Dr. Dunglison.

P. S.—Nearly all the persons alluded to are, or have been, in the Institution with which I have been, and am, connected.

It would appear, consequently, that the defect is at least as likely to be communicated hereditarily, in the case of the deaf and dumb, as in that of the blind. As respects, however, the subject agitated in the text, it would be necessary to have exact statistical information in regard to the progeny of those who have been *born* deaf and dumb, or blind, and of those who have *become* so after birth.

of near relations was unavoidable, and such varieties would necessarily be perpetuated. The race of Ham appears to have been separated, if not wholly, at least in part, from their brethren by the malediction of Noah; and, whether we consider, that a physical alteration was comprised in the malediction, or that such alteration might occur accidentally, as in the cases of those with supernumerary toes and fingers, the very fact of intermarriage with the descendants of the other sons of Noah being prevented by the curse pronounced on Ham (for many commentators read Ham for Canaan), would necessarily lead to a perpetuation of the adventitious modification.

But, it has been asked, if all mankind have descended from one family, which of the varieties now extant must be regarded as their representative? On this we have nothing but conjecture to guide us. It has been supposed, by some, to be more probable, that the changes induced upon mankind have been rather in consequence of the progress from a state of barbarism to one of refinement than the reverse; and hence—it has been conceived—that variety ought to be considered primary, which, through all the vicissitudes of human affairs, has remained in the most degraded condition, and in its structure differs most materially from the one that has uniformly enjoyed the greatest degree of civilization. Upon this principle, the Ethiopian would have to be regarded as the original type of our first ancestors; and such is the opinion of Drs. Prichard and Bostock, M. Marcel de Serres[1] and others. Blumenbach, however, maintains the converse view. Bishop Heber, again, suggests, whether the hue of the Hindoo, which is a brownish-yellow, may not have been that of our first parents; from which the transition, he thinks, to the white and black varieties, might be more easy and comprehensible. Philology occasionally aids us in our historical deductions, but the evidence afforded by it has to be received with caution. The Hebrew names, like all original appellations, in perhaps all languages, are generally expressive, and therefore worthy of consideration in questions of this nature. The Hebrew word Adam, (אדם) is not only the name of the first man, but it signifies man in the abstract, corresponding to the Greek, ανθρωπος, and the Latin, *homo*. We are told, in the sacred volume, that "in the day that God created man, in the likeness of God made he him; male and female created he them; and blessed them, and called their name Adam, in the day when they were created." The word Adam is derived from a Hebrew root, (אדם,) signifying "to be red," and accordingly, it has been thought probable, that the original hue of the first man was of that character.

The remarks already made render it unnecessary to inquire into the mode in which, according to the notions of Blumenbach,[2] Dr. S. S. Smith, of Princeton,[3] or Dr. Rush, the black colour of the Ethiopian has been produced. Blumenbach imagined, that the heat of the climate gives rise to an excessive secretion of bile; that in consequence of the connexion which exists between the action of the liver and the

[1] L'Institut, 13 Févr., 1850.

[2] De Gener. Human. Variet. Nat., p. 66, Gotting., 1795.

[3] An Essay on the Causes of the Variety of Complexion and Figure in the Human Species, Philad., 1787.

skin, an accumulation of carbonaceous matter takes place in the cutaneous vessels; and this process being continued for a succession of ages, the black colour becomes habitual. Dr. Smith had a similar opinion: he thought that the complexion in any climate will be changed towards black, in proportion to the degree of heat in the atmosphere, and the quantity of bile in the skin; and, lastly, Dr. Rush, in one of the strangest of the strange views that have emanated from that distinguished, but too enthusiastic, individual, has attempted to prove, "that the colour and figure of that part of our fellow-creatures, who are known by the epithet of negroes, are derived from a modification of that disease which is known by the name of leprosy." The following are his deductions from "facts and principles" urged in a communication read before the American Philosophical Society in 1792:[1]— "1. That all the claims of superiority of the whites over the blacks, on account of their colour, are founded alike in ignorance and inhumanity. If the colour of negroes be the effect of a disease, instead of inviting us to tyrannize over them, it should entitle them to a double portion of our humanity, for disease all over the world has always been the signal for immediate and universal compassion. 2. The facts and principles which have been delivered, should teach white people the necessity of keeping up that prejudice against such connexions with them as would tend to infect posterity with any portion of their disorder. This may be done upon the ground I have mentioned without offering violence to humanity, or calling in question the sameness of descent, or natural equality of mankind. 3. Is the colour of the negroes a disease? Then let science and humanity combine their efforts, and endeavor to discover a remedy for it. Nature has lately unfurled a banner upon this subject. She has begun spontaneous cures of this disease in several black people in this country. In a certain Henry Moss, who lately travelled through this city, and was exhibited as a show for money, the cure was nearly complete. The change from black to a natural white flesh colour began about five years ago at the ends of his fingers, and has extended gradually over the greatest part of his body. The wool, which formerly perforated the cuticle, has been changed into hair. No change in the diet, drinks, dress, employments, or situation of this man had taken place previously to this change in his skin. But this fact does not militate against artificial attempts to dislodge the colour in negroes, any more than the spontaneous cures of many other diseases militate against the use of medicine in the practice of physic. To direct our experiments upon this subject, I shall throw out the following facts:—1. In Henry Moss the colour was first discharged from the skin in those places on which there was most pressure from clothing, and most attrition from labour, as on the trunk of his body, and on his fingers. The destruction of the black colour was probably occasioned by the absorption of the colouring matter of the rete mucosum, or perhaps of the rete mucosum itself; for pressure and friction, it is well known, aid the absorbing action of the lymphatics in every part of the body. It is from the latter cause, that the palms of the hands of negro women,

[1] Transact. of the American Philosoph. Society, vol. iv.

who spend their lives at a washing tub, are generally as fair as the palms of the hands in labouring white people. 2. Depletion, whether by bleeding, purging, or abstinence, has been often observed to lessen the black colour in negroes. The effects of the above remedies in curing the common leprosy satisfy me that they might be used with advantage, in that state of leprosy, which I conceive to exist in the skin of the negroes. 3. A similar change in the colour of the negroes, though of a more temporary nature, has often been observed in them from the influence of fear. 4. Dr. Beddoes tells us that he has discharged the colour in the black wool of a negro by infusing it in the oxygenated muriatic acid, and lessened it by the same means in the hand of a negro man. The land-cloud of Africa, called, by the Portuguese, Ferrino, Mr. Hawkins tells us, has a peculiar action upon the negroes in changing the black colour of their skins to dusky gray. Its action is accompanied, he says, with an itching and prickling sensation upon every part of the body, which increases with the length of exposure to it so as to be almost intolerable. It is probably air of the carbonic kind, for it uniformly extinguishes fire. 5. A citizen of Philadelphia, upon whose veracity I have perfect reliance,[1] assured me that he had once seen the skin of one side of the cheek inclining to the chin, and of part of the hand in a negro boy, changed to a white colour by the juice of unripe peaches, (of which he ate a large quantity every year,) falling, and resting frequently upon those parts of his body.

"To encourage attempts to cure this disease of the skin in negroes, let us recollect that, by succeeding in them, we shall produce a large portion of happiness in the world. We shall in the *first* place destroy one of the arguments in favour of enslaving the negroes, for their colour has been supposed by the ignorant to mark them as objects of divine judgment, and by the learned to qualify them for labour in hot and unwholesome climates. *Secondly.* We shall add greatly to *their* happiness, for however well they appear to be satisfied with their colour, there are many proofs of their preferring that of the white people. *Thirdly.* We shall render the belief of the whole human race being descended from one pair easy and universal, and thereby not only add weight to the Christian revelation, but remove a material obstacle to the exercise of that universal benevolence which is inculcated by it."

Of late years, the question of the unity of the human family has been again agitated by distinguished individuals, and mainly on zoological grounds. Many years ago, it was ably argued by Mr. Lawrence,[2] whose views met with so much intolerance and persecution as even to affect his professional success, and social position,—that animals were created for special localities, to which they are often confined, unless conveyed elsewhere by human agency. "The question"—he remarks —"belongs properly to the domain of natural history and physiology;" and as such it has been examined by Professor Agassiz, Dr.

[1] Mr. Thomas Harrison.

[2] Lectures on Comparative Anatomy, Physiology, and Zoology, and the Natural History of Man, p. 166, Lond., 1844.

Morton[1] and others of this country, who accord, in the main, with Mr. Lawrence. Professor Agassiz[2] emphatically declares it to be inconsistent with the structure, habits, and natural instincts of most animals to suppose that they could have migrated over any great distances; and that "he is satisfied it was never meant in the sacred writings, that all men originated from a single pair, or that animals had a similar origin from one common centre, or from single pairs:" and, he adds, that "this doctrine of a unique centre of origin and successive distribution of all animals is of very modern invention, and can be traced back for scarcely more than a century in the records of our science." These views have been strengthened by his examination of Lake Superior, which lead him to affirm,[3] that "all the fresh water fishes of the district under examination are peculiar to that district, and occur no where else in any other part of the world. They have their analogues in other continents, but nowhere beyond the limits of the American continent do we find any fishes identical with those of the district, the fauna of which we have been recently surveying." "If"—he adds—"we face the fundamental question, which is at the bottom of this particular distribution of animals, and ask ourselves, where have all these fishes been created, there can be but one answer given, which will not be in conflict and direct contradiction with the facts themselves; and the laws that regulate animal life. The fishes and all other fresh water animals of the region of the great lakes must have been created where they live. They are circumscribed within boundaries over which they cannot pass, and to which there is no natural access from other quarters. There is no trace of their having extended further in their geographical distribution at any former period, nor of their having been limited within narrower boundaries. It cannot be rational to suppose that they were created in some other part of the world, and were transferred to this continent, to die away in the region where they are supposed to have originated, and to multiply in the region where they are found. There is no reason why we should not take the present evidence in their distribution as the natural fact respecting their origin, and that they are, and were from the beginning, best suited for the country where they are now found."[4]

It must be admitted that the zoological facts brought forward in recent periods more especially are of great weight in determining the question whether all mankind were originally descended from one pair, and all animals distributed from a common centre; and that a strong case has been made out in favour of the negative view.[5]

The whole subject of ethnology has received great attention of late years; and many valuable contributions have been made to it by distinguished investigators.[6]

[1] Hybridity in Animals and Plants considered in reference to the question of the Unity of the Human Species, in Amer. Jour. of Science and Arts, vol. iii., Second series, 1847.

[2] Christian Examiner, March, 1850, p. 185.

[3] Lake Superior; its Physical Characters, Vegetation, and Animals, compared with those of other and similar Regions, p. 375, Boston, 1850.

[4] See also, Agassiz and Gould, Principles of Zoology, p. 179, Boston, 1848.

[5] Agassiz, on the Diversity of Origin of the Human Races, in Christian Examiner for July, 1850.

[6] See, besides the authors already referred to, Dr. John Bachman, in various papers on the Unity of the Human Race, Charleston, 1850 to 1854; Dr. C. Caldwell,

CHAPTER V.

LIFE.

THE knowledge of the mode in which the various functions of the body are exercised constitutes the *science of life.* The manifestations of life have, consequently, been considered already. We have seen, that animal and vegetable substances possess the ordinary properties of matter, but that these properties are often singularly controlled, so that they are prevented from undergoing the changes that inevitably occur as soon as they become deprived of vitality. The human body is prone to decomposition. It is formed of substances extremely liable to undergo putrefaction, and is kept at a temperature most favourable for such change; yet, so long as life exists, the play of the ordinary affinities is prevented, and this constant resistance to the general forces of matter prevails throughout the whole of existence, even to an advanced old age, when, it might be supposed, the vital forces must be enfeebled almost to annihilation. The case of solution of the stomach after death, described in the first volume of this work, is an additional and forcible evidence of such resistance. So long as life continues, the gastric secretions exert no action on the organ, but, when it becomes extinct, the secretions act upon it as they do upon other dead animal matter.[1] What, then, is this mysterious power, possessed of such astonishing, incomprehensible properties? Our knowledge is limited to the fact above stated, that organized matter, in addition to the general physical and chemical forces, possesses one other,—the *vital force* or *principle* or *vitality,*—which, in activity, constitutes *life.* This force exists, not only in the whole, but in every part, of a living body; and its existence is evidenced by the unequivocal signs afforded by the various functions we have considered, as well as by others to be presently described. Yet it is not equally manifested in all organs; some appearing to be possessed of more

Thoughts on the Original Unity of the Human Race, Cincinnati, 1852; Dr. Robert Knox, The Races of Men—a fragment, London, 1850; Dr. Josiah C. Nott, on the Diversity of the Human Race; and, in connexion with Mr. Geo. H. Gliddon, Types of Mankind, or Ethnological Researches based upon the Ancient Monuments, Paintings, Sculptures and Crania of Races, &c., illustrated by selections from the inedited papers of Samuel George Morton, M. D.; and by additional contributions from Prof. L. Agassiz, LL. D., W. Usher, M. D., and Prof. H. S. Patterson, M. D., Philad., 1854; Lieut. Col. Charles Hamilton Smith, The Natural History of the Human Species, &c., Amer. edit., by S. Kneeland, Jr., M. D., Boston, 1851; Rev. Thomas Smyth, D. D., the Unity of the Human Race proved to be the Doctrine of Scripture, Reason and Science, &c., New York, 1850.

[1] Much has been said of late in regard to this force, and its correlation with the physical forces, but without much light having been shed on the subject. They, who are partial to such inquiries, may consult the Memoir of Professor Grove on the subject, London, 1843; Dr. Carpenter, Philosophical Transactions, 1850, and Mr. Newport, Annals of Natural History, Nov., 1850; also, Professor Samuel Jackson, Introductory Essay on the Human Organism and its Forces, with remarks on Dr. Lehmann's Doctrine of Vital Forces, in Manual of Chemical Physiology, from the German of Prof. C. G. Lehmann, M. D., translated, with notes and additions, by J. Cheston Morris, M. D., Philad., 1856.

vitality than others,—a result probably produced by diversity of texture, as it would seem irrational to admit a different kind of vital force wherever its manifestations appear to be modified.

Various attempts have been made to define life; nothing, however, is more difficult. "I quote," says Professor Flourens,[1] "the definition of an ancient physiologist: 'Life is the opposite of death.' One laughs. I quote the definition of Bichat: 'Life is the aggregate of functions that resist death.' One laughs no longer. Bichat, however, has only repeated, in terms a little emphatic, the simple (*naïve*) definition of the ancient physiologist." Professor Flourens attempts none of his own.

Whatever definition we admit must comprise the idea of internal change, activity, or movement under favourable circumstances.[2]

Admitting the existence of a controlling force of life, what, it may be asked, are the functions through which it immediately acts in keeping up the play of the living machine? It has been elsewhere seen, that, in animals the reciprocal action of innervation, respiration and circulation is indispensable, and that if one of these functions be arrested, the other quickly ceases. This is only applicable, however, to animals; and it has been doubted, whether it applies to all and every part of them; whilst to the vegetable it is altogether inapplicable, unless we regard it, with some physiologists, as possessing a rudimental nervous system.[3]

The medulla oblongata more especially has been considered to preside over the life of vertebrated animals. "There is," observes an eminent physiologist, "in the nervous system, a point situated between the parts of sensation and those of motion—nearly as the cervix (*collet*) of the vegetable is between the stalk and the root;—a point which every impression must reach, in order to be perceived; from which the orders of the will must set out in order to be executed; to which it is sufficient for the parts to be attached to live; from which it is sufficient for them to be detached to die;—a point, which consequently forms the central focus (*foyer*), the common bond; and, as M. de Lamarck has so happily said of the *collet* of the vegetable, the vital knot (*nœud vital*) of the system."[4] In the medulla oblongata, is doubtless, seated the nervous centre of respiration; yet it may be removed in the batrachia; and, in favourable conditions, Dr. Brown-Séquard[5] has known the animal live more than four months after its removal; and "in appearance" remain in good health. The greatest difference was found to exist in the after duration of life in animals of different species. In the batrachia it might be reckoned by months; in some reptilia by weeks; in other reptilia and fishes by days; in hibernating mammalia by hours; and in birds and non-hiber-

[1] Brachet, Recherches Expérimentales sur les Fonctions du Système Nerveux Ganglionnaire, &c., Paris, 1830; and Physiologie Élémentaire de l'Homme, Paris et Lyon, 1855.

[2] De la Longévité Humaine et de la Quantité de Vie sur le Globe, 2de édit., p. 195, Paris, 1855.

[3] Vol. 1, p. 40. For various definitions, see Bérard, Cours de Physiologie, i. 11, Paris, 1848; and Béraud, Manuel de Physiologie de l'Homme, p. 9, Paris, 1853.

[4] Flourens, Recherches Expérimentales sur les Propriétés et les Fonctions du Système Nerveux, p. 241, Paris, 1824; and De la Longévite Humaine, &c., edit. cit., p. 195.

[5] Medical Examiner, Sept., 1852, p. 565.

nating mammalia by minutes. Death in such cases he refers to insufficiency of respiration.[1]

Prior to the time of Haller, the nervous system was looked to as the great source of power in the animal body; and the contractile action of the muscles,—described at length under the head of Muscular Motion,—was considered to be wholly derived from the nerves, which were supposed to transmit the power to the muscular fibre as it was called for,—accurately regulating the quantity supplied. Haller contended for a *vis insita*, a power of *irritability* or *contractility*, essentially residing in the muscles themselves, independently of any condition of the nervous system, and called into action by stimuli, of which the nervous influence is one,—contributing, however, like other stimuli, to exhaust it, instead of furnishing any fresh supply. We have elsewhere shown, that a muscle is capable of being thrown into contraction after a limb has been removed from the body, and for a considerable period after the cessation of respiration, circulation, and consequently of innervation, provided the appropriate stimuli be applied, so as to excite the vis insita, which remains in the muscle for some time after dissolution; and if all the nerves, supplying the limbs of a frog, be divided and cut out close to the place where they enter the muscles, the muscles will still retain their contractility in as great a degree as when the nerves were entire. It has been affirmed by an excellent observer,[2] that after tying the femoral artery or vein, or dividing the sciatic nerve in frogs, the full strength of the muscles remained unaltered for several days,—in one case as many as twelve. They, who believe that the contractility of muscles is wholly derived from the nervous system, maintain, however, that in such case the stimulus may still act through the medium of portions of nerves always remaining attached to the muscle, however carefully attempts may have been made to remove them; and some have supposed, that these nervous fibres may even constitute an essential part of the muscular fibre. The most satisfactory reply, that has been made to this argument, is the following experiment of Dr. Wilson Philip.[3] All the nerves supplying one of the hind legs of a frog were divided, so that it became completely paralytic. The skin was removed from the muscles of the leg, and salt sprinkled upon them, which, being renewed from time to time, excited contraction in them for twelve minutes: at the end of this time they were found no longer capable of being excited. The corresponding muscles of the other limb, in which the nerves were entire, and of which, consequently, the animal had a perfect command, were then laid bare, and the salt applied to them in the same way. In ten minutes, they ceased to contract; and the animal had lost command of them. The nerves of this limb were now divided, as those of the other had been, but the excitability of the muscles to which the salt had been applied was gone. It caused no contraction in them. After the experiment, the muscles of the thighs in both limbs were found to contract forcibly on the appli-

[1] Medical Examiner, Sept., 1852, p. 569.

[2] Valentin, Lehrbuch der Physiologie des Menschen, ii. 176–192.

[3] An Experimental Inquiry into the Laws of the Vital Functions, &c., p. 100, Lond., 1817.

cation of salt. It excited equally strong contraction on both sides. In this experiment, the excitability of the muscles, whose nerves were entire, was soonest exhausted; and hence Dr. Philip[1] properly concluded, that the nervous influence, far from bestowing excitability on the muscles, exhausts it like other stimuli; and that excitability or irritability is a property of the muscle itself. This is confirmed by the fact, that, when the vital properties of nerves are destroyed by the application of narcotic substances, the irritability of the muscle to which they are distributed may remain for some time longer; so that they must be independent of each other. Experiments have been performed by Harless,[2] on animals rendered completely insensible by inhalation of ether, which confirm this view. He found, that even when the nervous system had been rendered by the action of ether utterly incapable of conveying a galvanic stimulus applied either to the nervous centres or to the nervous trunks; the same stimulus, applied directly to the muscles, would immediately throw them into powerful contraction. Dr. Madden, too, communicated some years ago, to the British Association at its meeting in Edinburgh, the results of the agency of narcotics in destroying the power of nervous conduction, without diminishing muscular contractility in an equal degree.[3]

The opinion of Professor Müller is, that if muscular irritability be not dependent upon the brain and spinal cord, they supply some influence essential to its exercise; and in confirmation of this he lays much stress on the loss of irritability by muscles within a few weeks after the section of their nerves. This, however, has been shown by Dr. J. Reid[4] to be owing to the altered nutrition consequent on their disuse. He divided the spinal nerves as they lie in the lower part of the spinal canal in four frogs, and both posterior extremities were thus insulated from their nervous connexions with the cord. The muscles of the paralysed limb were daily exercised by a weak galvanic battery; whilst those of the other limb were permitted to remain quiescent. This was continued for two months; at the end of which time the muscles of the exercised limb retained their original size and firmness, and contracted vigorously, whilst those of the quiescent limb had shrunk to at least one-half of their former bulk, and presented a marked contrast with those of the exercised limb. The muscles of the quiescent limb still retained their contractility, even at the end of two months; but Dr. Reid thought there could be little doubt, that, from their imperfect nutrition, and the progressing changes in their physical structure, this would in no long time have disappeared, had circumstances permitted the prolongation of the experiment.

The experiments of Dr. Brown-Séquard[5] are highly confirmatory of Haller's doctrine. He found, that muscles and nerves which had lost their excitability, could have it restored by arterial blood sent into their vessels. He frequently observed, also, that muscles,

[1] Lond. Med. Gazette, March 18 and 25, 1837.
[2] Müller's Archiv., H. ii. S. 228, Jahrgang, 1847.
[3] Brit. and For. Medico-Chirurg. Review, July, 1848, p. 245.
[4] Edinburgh Monthly Journal of Med. Science, May, 1841.
[5] Med. Examiner, August, 1852, p. 485, and May, 1853, p. 280.

paralysed for five days or a little more, in consequence of the division of their nerves, remained much longer contractile after the death of the animal than the sound muscles; which—as he well remarks—would scarcely be the case if the excitability were communicated to muscles by the nervous system.

This essential characteristic of living bodies—manifested in their moving responsive to some stimulus—is a distinct vital property, to be noticed presently, which is not confined, as Haller supposed, to the muscular structure, but exists over the whole body; and in confirmation of its not being dependent upon the nerves, is the fact of its presence in the vegetable as well as in the animal. Many plants exhibit the property in a remarkable manner. The barberry bush is one of these. In this flower, the six stamens, spreading moderately, are sheltered under the concave tips of the petals, till some extraneous body, as the feet or trunk of an insect in search of honey, touches the inner part of each filament near the bottom. The irritability of that part is such, that the filament immediately contracts there, and consequently strikes its anther, full of pollen, against the stigma. Any other part of the filament may be touched without this effect, provided no concussion be given to the whole. After a while, the filament retires gradually, and may be again stimulated; and when each petal, with its annexed filament, has fallen to the ground, the latter, on being touched, shows as much irritability as ever. In another plant,—*Cistus helianthemum*, *dwarf cistus* or *lesser sunflower*,—the filaments, when touched, execute a motion, the reverse of that of the barberry. They retire from the style and lie down, in a spreading form, upon the petals. Owing to the possession of this property, *Apocynum androsæmifolium* or *dogsbane* is extremely destructive to insect life. Attracted by the honey on the nectary of the expanded blossom, the instant the trunk of the fly is protruded to feed on it, the filaments close, and, catching the fly by the extremity of its proboscis, they detain the insect until its struggles end in death occasioned apparently by exhaustion alone. The filaments then relax, and the body falls to the ground.[1] These are only evidences, however, of particular parts possessing an unusual degree of irritability. The property exists in every part of the plant, and, as in the animal, is the essential characteristic of life. It forms a medium of communication between the various parts of the living machine, and is excited to action by extraneous influences. All its movements, however, appear to be dependent upon appropriate stimuli, and are, consequently, passively exercised.

In all organized bodies a force or impulse exists, which gives occasion to the formation of its constituent tissues and organs according to a definite plan; gradually developing the plant from the seed, as it does the animal from the ovum or egg, so unerringly, that no confusion results; and enabling the shape, size, and duration of the oak to be as assuredly pronounced from the inspection of the seed, as those of the bird can be from its ovum or egg:—a vital force, in other words, is present, which presides over, as it were, and directs the movements of living bodies in their structural developement, and

[1] Sir J. E. Smith, Introduction to Botany, p. 211.

whose agency does not cease until every trace of movement is impracticable; and the being—animal or vegetable—ceases to live. The germ of the chick is surrounded in the egg by the nourishment needed for its developement; but, so far as the eye can see, when aided by the most powerful microscope, that germ possesses no nerves; no blood; both of which have been regarded by many as indispensable to the growth of parts in the fully developed animal. Yet gradually, under special arrangements of cells, tissue after tissue becomes formed; organ after organ is evolved in succession, until the full period of incubation is attained, when the young animal breaks the shell to assume an independent existence, perfect in an organization moulded and fashioned under its own life power. Cells exist at first without the slightest appearance of bloodvessels; gradually, however, minute dots become perceptible, which coalesce; and blood is seen before continuous vessels are prepared to receive it. Vessels exist before the heart. Vascular tubes are formed and become filled with blood. At first, these tubal fragments are seen to be distinctly separated from each other; but, subsequently, they become united; and when a powerful central and muscular organ—the heart—is superadded, the apparatus of the circulation is complete, and fitted for its great objects. So is it in regard to the neurine or nervous matter, which, in the aggregate, forms the nervous system. Evolved in distinct portions—nerve points—in detail as it were, it is not adapted for that wonderfully perfect internuncial system of association, which unites the various parts of a complicated and dependent machine, until the separate portions have united, and the various ramifications have become connected with central ganglions, to which, in the higher organisms, impressions, received by the sentient extremities of the nerves, have to be conveyed.

We thus comprehend, that *life power* and *nerve power* are by no means identical;—that the former exists before nerves or vessels are developed; and in the vegetable kingdom throughout, not in the humblest moss only, but in the fairest flower of the parterre, and in the gigantic occupant of the forest, we may in vain look for aught resembling the nervous system of man and the higher animals. It is true—as before remarked—that the pith of the vegetable has been likened by Brachet and some others to the neurine of the animal, and a ganglionic nervous system has been ascribed to the former; but how forced must be the analogy between the morphology of vegetable pith and that of animal neurine, and how defective the evidence in favour of their functional identity or even resemblance!

If this, then, be conceded, we must equally admit, that all the functions, which are exercised by vegetable bodies, are carried on without nervous agency. Nutriment must be received from without; the fluid which passes from cell to cell, or in vessels formed by the aggregation of such cells, and which is the pabulum for all nutritive action, must be in constant progression, and be conveyed to the surface of the leaves, in order that it may receive from the air the same kind of indispensable influence, which is impressed upon the blood in the lungs: from this fluid must be formed every secretion—bland or acrid, fragrant or repulsive, of which the vegetable kingdom presents so vast a variety. Every product of nutrition, from the coarsest vegetable fibre

to the most delicate and exquisitely formed petal;—all can be, and are, evolved, under the influence of that pervading life power, as perfect in its kind as in the most perfect animal. In the lowest confines of the animal creation, where—as in the monad or in the simple primordial cell—we may in vain look, with the aid of the most powerful microscope fabricated by the most skilful of modern mechanicians, for the presence of nervous centres or even of rudimental nerves—nerve points—all the organic functions are accomplished much in the same manner as in the vegetable; and it is only as we ascend the scale, and discover in the series a more and more complicated nervous apparatus, that the problem becomes more complicated. The nervous system is destined for the most elevated *rôle;* and whilst its functions are most mysterious and pervading, so as to modify materially the degree of the nutritive actions, the conclusion is irresistible, that they are not carried on by it; but are the result of the life or instinctive force which is seated in every living tissue.

To this life force whose movements or impulsions are active and varied, the term *instinct* has been appropriated by Virey,[1] Fleming,[2] Good,[3] and others. It is an extension of the ordinary acceptation of the term; but enables us to understand the phenomena better than when we restrict it to those manifestations of man, or animals, that bear the semblance of reason. It is this power, which, according to those gentlemen, regulates the movements, that are requisite to obtain a supply of food, to remove or counteract opposing obstacles, and to fly from impending danger, or repair injuries. "In every organized system," says Dr. Good,[4] "whether animal or vegetable, and in every part of such system, whether solid or fluid, we trace an evident proof of that controlling, and identifying power, which physiologists have denominated, and with much propriety, the principle of life. Of its cause and nature we know no more than we do of the cause and nature of gravitation, or magnetism. It is neither essential mind nor essential matter; it is neither passion nor sensation; but, though unquestionably distinct from all these, is capable of combining with any of them; it is possessed of its own book of laws, to which, under the same circumstances, it adheres without the smallest deviation; and its sole and uniform aim, whether acting generally or locally, is that of health, preservation, or reproduction. The agency by which it operates is that which we denominate or should denominate instinct, and the actions by which its sole and uniform aim is accomplished are what we mean, or should mean, by instinctive actions; or to speak somewhat more precisely, instinct is the operation of the livng principle, whenever manifestly directing its operations to the health, preservation or reproduction of a living frame, or any part of such frame. The law of instinct, then, is the law of the living principle; instinctive actions are the actions of the living principle; and either is that power, which characteristically distinguishes organized from unorganized matter, and pervades and regulates the former, uniformly operating by definite means in definite

[1] Art. Instinct, in Dict. des Sciences M'dicales, xxv. 367.
[2] Philosophy of Zoology, i. 14, Edinb., 1822.
[3] Book of Nature, ii. 114, London, 1826.
[4] Ibid., ii. 132.

circumstances, to the general welfare of the individual system or of its separate organs, advancing them to perfection, preserving them in it, or laying a foundation for their reproduction, as the nature of the case may require. It applies equally to plants and to animals, and to every part of the plant, as well as to every part of the animal, so long as such part continues alive. It is this, which maintains from age to age, with so much nicety and precision, the distinctive characters of different kinds and species; which carries off the waste or worn out matter, supplies it with new, and in a thousand instances, suggests the mode of cure, or even effects the cure itself, in cases of injury or disease. It is 'the divinity that stirs within us' of Stahl, the *vis medicatrix naturæ* of Hoffmann and Cullen and the physicians of our day, &c. &c."

Of the existence of this instinctive force we may adduce a few more examples from both the vegetable and the animal kingdom. When the seed of a plant is deposited in the ground, under circumstances favourable for its developement, it expands, and the root and stem are evolved. The root descends into the ground, manifestly not from the laws of gravitation, but owing to some inherent force, inasmuch as it penetrates the earth, which is of much greater specific gravity than itself. The stem, too, bursts through the earth, and rises into the air, notwithstanding the air is of much less specific gravity; until having attained the height to which the action of the vital force limits it, its upward developement ceases. It rarely happens, however, that the root is capable of procuring nourishment sufficient for its future developement in immediate contact with it. It, therefore, sends out numerous filamentous radicles in all directions to search after food, and convey it to the proper organs. The number and direction of these filaments, and the distance to which they extend, are regulated by the necessities of the plant, and the supply of the soil. A strawberry offset, planted in sand, will send out almost all its runners in the direction in which the proper soil lies nearest; and few, and sometimes none, in the direction in which it lies most remote.[1] When a tree, which requires much moisture, has sprung up, or been planted in a dry soil, in the vicinity of water, it has been observed, that a much larger portion of its roots has been directed towards the water, and that when a tree of a different species, and which requires a dry soil, has been placed in a similar situation, it has appeared, in the direction given to its roots, to have avoided the water and moist soil. When a tree, too, happens to grow from seed on a wall, it has been seen, on arriving at a certain size, to stop for a while, and send down a root to the ground. As soon as this root has been established in the soil, the tree has continued increasing to a large magnitude. The fact has been often noticed with respect to the ash,—a tree, which in consequence of the profusion of its seed, is found more often scattered in wild and singular places, than in any other not propagated by the agency of birds, or conveyed by the winds.

We find, in all cases, that if the roots of a plant, spreading in search of nourishment, meet with interruption in their course, they do not arrest their progress, but either attempt to penetrate the opposing body,

[1] Fleming, op. citat., p. 16.

or avoid it by altering their direction. Dr. Fleming[1] states that he has repeatedly seen the creeping root of *Triticum repens* or *couch grass* piercing a potato, that had obstructed its course. It is well known, too, that roots will pass under a stone wall or a ditch, and rise up on the opposite side. A striking case of this nature was communicated to the author, by his venerable friend, the late Ex-President Madison. The wooden pipes, for the conveyance of water to Mr. Madison's establishment, having become obstructed, they were carefully examined; when it was found, that the roots of a honeysuckle, growing immediately above a plug, made of the wood of *Liriodendron tulipifera* or *American poplar*, which is of soft consistence, had penetrated the plug in various places to reach the water, and formed an agglomerated mass in the pipe which completely precluded the passage of water along it.

The nearest approximation to these manifestations of instinct in the animal, occurs in the formation of the new being, and in the first actions that take place after birth. From the moment of the admixture of substances furnished by the parents at a fecundating copulation, there must be a force existing in the embryo, which directs the construction and arrangement of its organs after a definite manner; and always according to that peculiar to the species. In the egg, this is seen most distinctly. The germ of the chick is surrounded by the nourishment requisite for its formation, until the young animal breaks the shell. At this time, it has within it a portion of nutriment derived from the yolk drawn into its body. This supplies its wants for a short period; but it soon becomes necessary, that it should select and collect food for itself, and we observe it throwing its various organs into action for prehension, mastication, deglutition, &c., as if it had been long accustomed to the execution of these functions. In the formation of the human fœtus in utero the same instinctive action is observable in the successive evolution of organs, and in the limitation of the body to a determinate shape, size, structure, &c.; and when these requisites have been attained, the child bursts the membranous envelope, and is extruded, to maintain thenceforth an existence independent of the mother. More helpless, however, than the young of the animal kingdom in general, the infant requires the fostering care of the parent for the purpose of supplying it with the necessary nutriment; but as soon as food is conveyed to the lips, the whole of the complicated process of deglutition is effected for the first time, with the same facility as after long practice. As we descend in the animal kingdom, we find these inward actions that constitute instinct more and more largely exhibited. In the quadruped, it is not necessary, that the nipple should be applied by the mother to the mouth of the new-born animal. It is sought for by the latter; discovered, and seized hold of, by the appropriate organ of prehension, the mouth. The lips are applied; the air is exhausted; and the milk flows according to exact principles of hydrostatics, but without the animal having the least knowledge of the physical process it accomplishes. Naturalists, indeed, assert, that before the calf has been more than half extruded from the mother, it has been seen to

[1] Op. citat., p. 18.

turn around, embrace and suck the maternal teat. As we descend still farther in the scale of creation, we discover the manifestations of instinct yet more signally developed; until, ultimately, in the very lowest classes of animals, the functions are exercised much in the same manner as in the vegetable; and appear to be wholly instinctive, without the slightest evidence of that intelligence, which we observe in the upper classes of the animal kingdom, and pre-eminently in man. This, however, applies only to the very lowest classes; for, a short way higher up the scale, we meet with apparent intelligence, united with instinct, in a manner that is truly surprising and mysterious.

Again, the similarity of the actions of the instinctive principle in the animal and the vegetable is exhibited by the reparatory power which both possess when injuries are inflicted on them. If a branch be forcibly torn from a tree, the bark gradually accumulates around the wound, and cicatrization is at length accomplished. The great utility of many of our garden vegetables,—as spinach, parsley, cress, &c.—depends upon the possession of a power to repair injuries, so that new shoots speedily take the place of the leaves that have been removed. Similar to this is the reparatory process, instituted in the lobster that has lost its claw, the water-newt that has lost an extremity, or an eye; in the serpent deprived of its tail, and the snail that has lost its head. These parts are reproduced as the leaves are in the spinach or parsley. Few animals, however, possess the power of restoring lost parts; whilst all are capable of repairing their wounds when not excessive, and of exerting a sanative power, when labouring under disease. If a limb be torn from the body, provided the animal should not die from hemorrhage, a reparatory effort is established, and if the severity of the injury should not induce too much irritation in the system, the wound gradually fills up, and the skin forms over it. To a lesser extent we see this power exerted in the healing of ordinary wounds, and in the cementing of broken bones; and although it may answer the purpose of the surgeon to have it supposed, that he is possessed of healing salves, &c., he is well aware, that the great art in these cases is to keep the part entirely at rest, whilst his salves are applied simply for the purpose of keeping the wound moist; the edges in due apposition, where such is necessary; and preventing extraneous bodies from having access to it;—his trust being altogether placed in the sanative influence of the instinctive power situate in the injured part, and in every part of the frame.

It is to this power, that we must ascribe all the properties, assigned to the famous *sympathetic powder* of Sir Kenelme Digby,—which was supposed to have the wonderful property of healing wounds, when merely applied to the bloody clothes of the wounded person, or to the weapon that had inflicted the mischief;—a powder, which, at one time, enjoyed the most astonishing reputation.[1] The wound was, however, always carefully defended from irritation by extraneous substances; and it has been suggested, that the result furnished the first hint, that led surgeons to the improved practice of healing wounds by what is technically called the *first intention*. It is to this instinctive principle,

[1] A Late Discourse made in a Solemn Assembly of Nobles and Learned Men at Montpellier in France; by Sir Kenelme Digby, Knight, &c., London, 1658.

so clearly evinced in surgical or external affections, but at times, not less actively exerted in cases of internal mischief, that the term *vis medicatrix naturæ* has been assigned; and, whatever may be the objections to the views entertained regarding its manifestations in disease, that such a power exists can no more be denied than that organized bodies are possessed of the vital force. We have too many instances of recovery from injuries, not only without the aid of the practitioner, but even in spite of it, to doubt for a moment, that there is, within every living body, a force or impulse manifestly directed to the health and preservation of the frame, and of every part of it.

So far, then, it is manifest, the instinctive actions of the animal and vegetable are exerted according to the same laws, and probably through similar organs. This, at least, applies to the lowest of all animated beings, where the difference between them and the vegetable is small indeed. It applies equally to the human fœtus, which can be considered but to vegetate during the greater part of utero-gestation; and even for some time after birth its actions are purely instinctive, and differ but little from those of the vegetable, except that, owing to the morphology of its nervous system, the acts are of a more complicated character. It is only when the brain has become duly developed, and the external senses fully so, that it exhibits so decidedly the difference between those acts, which it had previously accomplished instinctively, and the elevated phenomena of sensibility, which man enjoys so pre-eminently, but are likewise possessed, to a greater or less extent, by the whole animal creation.

The cells of the ordinary honeycomb are intended for the larvæ of the different varieties of the occupants of the hive. These cells are usually placed horizontally, with their mouths opening towards the sides of the hive. The bottom of the cells, instead of forming one flat square, is composed of three lozenge-shaped pieces, so united as to make the cell end in a point; consequently, the whole forms an hexagonal tube, terminating in a pyramidal cavity. If the two cells had been a single hexagonal tube, intersected in the middle by a flat, instead of a pyramidal, division, not only would the shape have failed to answer the purpose of the bees, but more wax would have been expended in its construction. Hence, it would seem, that both the body and base of the tube are adapted for their object; the greatest strength and the greatest capacity being obtained with the least expenditure of wax in an hexagonal tube with a pyramidal base. Réaumur, when inquiring into the habitudes of these industrious animals, requested König, an able mathematician, to solve the following question:—Among all hexagonal tubes with pyramidal bases, composed of three similar and equal rhombs, to determine that which, having the same capacity, can be constructed with the least possible quantity of matter? König, not aware of the precise object of Réaumur's inquiry, solved the problem, and found,—that if three rhombs or lozenges are so inclined to each other that the great angles measure 109° 26′, and the little angles 70° 34′, the smallest possible quantity of matter will be needed. Maraldi measured the angles actually formed at the bottom of a cell, and found that the great angles gave 109° 28′ and the little 70° 32′.[1] All this,

[1] See, also, Mr. Maclaurin, Philosophical Transactions, vol. ix.

however, may be ascribed to blind instinct, proceeding uniformly in the same track, without any evidence of the admixture of reason; but we have innumerable instances, in the same insects, to show, that their operations are varied according to circumstances, and that intelligence is manifestly expended in the adaptation of means to definite purposes. Of this we shall give but one example. Huber, whose inquiries into this part of entomology have been singularly minute and accurate, having had great ravages committed on his hives by the *sphinx atropos* or *death's head moth*, determined to construct a grating, which should admit the bee but not the moth. He did so, and the devastation ceased. He found, however, that in hives, not protected by his agency, the bees had adopted a similar expedient for their defence; and these defences were variously constructed in different hives. "Here, was a single wall whose opening arcades were disposed at its higher part; there, were several bulwarks behind each other, like the bastions of our citadels: gateways, masked by walls in front, opened on the face of the second rows, while they did not correspond with the apertures of the first. Sometimes, a series of intersecting arcades permitted free egress to the bees, but refused admittance to their enemies. These fortifications were massy, and their substance firm and compact, being composed of propolis and wax."

Take, again, the case of the solitary wasp, so graphically given by the Rev. Sydney Smith.[1] "She digs several holes in the sand, in each of which she deposits an egg, though she certainly knows not that an animal is deposited in that egg,—and still less that this animal must be nourished with other animals. She collects a few green flies, rolls them up neatly in separate parcels (like Bologna sausages), and stuffs one parcel into each hole where an egg is deposited. When the wasp-worm is hatched, it finds a store of provisions ready made; and what is most curious, the quantity allotted to each is exactly sufficient to support it, till it attains the period of wasphood, and can provide for itself. This instinct of the parent wasp is the more remarkable as it does not feed upon flesh itself. Here the little creature has never seen its parent; for, by the time it is born, the parent is always eaten by sparrows; and yet, without the slightest education, or previous experience, it does everything that the parent did before it. Now the objectors to the doctrine of instinct may say what they please; but young tailors have no intuitive mode of making pantaloons;—a new-born mercer cannot measure diaper;—nature teaches a cook's daughter nothing about sippets. All these things require with us seven years' apprenticeship; but insects are like Molière's persons of quality:—they know everything (as Molière says), without having learnt anything;—'Les gens de qualité savent tout, sans avoir rien appris.'"

It would be endless, and beyond the design of this work, to enumerate the various evidences of intelligence exhibited by the insect tribe, in fulfilling the ends for which they have been destined by the Great Author of nature.

In all our reasonings on the subject of instinct, we must be com-

[1] Elementary Sketches of Moral Philosophy, p. 244, London, 1850; see, also, Laycock, in Brit. and For. Med.-Chir. Rev., July, 1855, p. 166.

pelled to admit, in the case of most animals at least, a degree of intelligence that strikingly modifies those actions, the impulse to which is doubtless laid in organization. The precise line of demarcation between instinctive acts and reason cannot, however, be established; and this has led some philosophers to call in question the existence of the former.

It is owing to the union of intelligence with instinct, that we find animals accommodating themselves to circumstances, so that if prevented from adopting the habits that belong to the species, they have recourse to others as similar as possible. Thus, if a bird be prevented from building its nest in a particular situation, or from obtaining the material, which birds of its own species employ, it has recourse to other materials and to another situation, as like those that are appropriate to it as is practicable. The rook usually and instinctively builds its nest on the summit of the tallest trees; but Dr. Darwin,—who is one of those that call in question the influence of instinct,—asserts, that in Welbourn churchyard, a rookery was formed on the outside of the spire, and on the tops of the loftiest windows. There had formerly been a row or grove of high trees in the neighborhood, which had been cut down; and, in consequence, the birds exhibited the union of intelligence with instinct, by building on the lofty spire and windows. In like manner, the jackdaws of Selbourne, according to Mr. White, not finding a sufficiency of steeples and lofty houses on which to hang their nests in that village, accommodated themselves to circumstances, and built them in forsaken rabbit burrows.[1] In Africa, which abounds in numerous beasts and birds of prey, all the feebler species of the feathered tribe would seem to have contrived some means of protection and security for their reproduction. Some so construct their nests, that they can only be entered by one small aperture; others suspend them from the extremities of small branches of trees. A species of *loxia* always hangs its nest from a branch extending over a river or pool, the opening into its long neck almost touching the water. "A note in my Journal,"—says Sir John Barrow,[2]—"observes, that the sparrow, in Africa, hedges round its nest with thorns; and even the swallow, under the eaves of houses, or in the rifts of rocks, makes a tube to its nest of six or seven inches. The same kinds of birds in Northern Europe, having nothing to fear from monkeys, snakes, or other noxious animals, construct open nests; and I ask is this difference the effect of mere accident or of design? Is it, I might have added, the effect of imitation or observation?"

By Stahl,[3] and the animists in general, as well as by more recent philosophers, all the phenomena of instinct have been referred to experience, so obscure as not to be easily traceable, but not the less certainly existent. The insect tribes, however, furnish us with many cases where the young beings can never see their parents, and can, of course, derive no benefit from the experience of progenitors; yet their habits are precisely what they have probably ever been; so uniform, indeed, as to compel us to refer them to some constant impulse con-

[1] Natural History of Selbourne, with additions, by Sir W. Jardine, Amer. edit., p. 82, Philada., 1832.
[2] An Autobiographical Memoir of Sir John Barrow, Bart., p. 193, Lond., 1847.
[3] Theoria Vera Medica, Hal., 1737.

nected with their special organization, and, consequently, instinctive. In support of the existence of these natural impulsions, the common occurrence of a brood of young ducks, brought up under a hen, may be mentioned.[1] These little beings, soon after they have broken the shell, and contrary to all the feelings and instincts of the foster-mother, seek the water, and suddenly plunge into it, whilst the hen herself does not dare to follow them. By what kind of experience or observation,—it has been asked,—by what train of thought or reasoning has the scarcely fledged brood been able to discern that a web-foot adapts them for swimming? Any experience they can have derived must have taught them to shun the water; yet, notwithstanding this, instinct points out to them habitudes for which they are adapted, and its indications are obeyed in spite of every kind of counter-experience. It is impossible to refer these acts to imitation, for there is no opportunity afforded for it. Sir James Hall, cited by Mr. Dugald Stewart in his "Lectures," hatched some chickens in an oven; and within a few hours after the shells were broken, a spider was turned loose before the newly-hatched brood, which had not proceeded many inches, before it was descried by one of them, and devoured.[2] Attempts have occasionally been made to domesticate the *wild turkey* of this continent, by bringing the young up under the common turkey, but they have always resumed the way of life to which instinct directed them, when opportunity offered; in accordance with the Horatian maxim:

"Naturam expellas furcâ, tamen usque recurret."

Mr. Madison reared, with great care, a young hawk, which, for a long time, associated with the young of the poultry, without exhibiting the slightest carnivorous or migratory propensity; until, on one occasion, whilst some of his friends were admiring its state of domestication, it suddenly arose in the air, darted down, and seized a chicken, with which it flew to a neighbouring tree, and, after it had finished its repast, took flight, and was never seen afterwards.

Instinct, then, is possessed by every organized body, animal and vegetable; whilst intelligence is the attribute of those only that are endowed with a certain nervous developement. The two are, therefore, manifestly distinct;—the former predominating over the latter in the lower classes of animals; whilst, in the upper classes, intelligence becomes more and more predominant, until, ultimately, in man, it is so ascendant as to appear to be the main regulator of the functions; indeed, some have altogether denied the existence of instinct in him. Instinct is seated in every part of a living body; is totally independent of the nervous system; occurs in the vegetable and the zoophyte unprovided with nerves, or at least in which nerves have never been discovered; whilst intelligence is always accompanied by a nervous system, without which, indeed, its existence is incomprehensible. How can we, consequently, accord with those physiologists who place the seat of instinct in the organic nervous system, or in the reflex or excitory motory system of nerves; and that of intelligence in the brain? Where is the organic nervous system of the zoophyte, and *à fortiori* of

[1] Good's Book of Nature, 3d edit., ii. 107, Lond., 1834.

[2] Rev. Sydney Smith, op. cit., p. 243.

the vegetable? Or how can we admit the seat of the various instincts to be in the encephalon, seeing that we have them exhibited where there is neither encephalon nor anything resembling one! The acephalous fœtus undergoes its full developement in other respects in utero, with the same regularity as to shape and size as the perfect fœtus; and can we deny it the existence of instinct? Yet, in the upper classes of animals especially, many of the manifestations of instinct are effected through the nervous system, which, in them, as we have elsewhere seen, seems to hold in control the various functions of the frame, and to be one of the two great requisites for the existence of vitality. The instinctive action in the appropriate organ, which gives rise to the internal sensations of hunger, thirst, &c., is communicated to the great nervous centres by the nerves; the encephalon responds to the impression, and excites, through the medium of the nerves, the various organs into action which are calculated to accomplish the monitions of the instinct.

What is the nature of this instinctive force? Of this we know no more than we do of the nature of life, of which it is one of the manifestations. It is equally inscrutable with the imponderable agents, light, caloric, electricity, and magnetism, or with the mode of existence of the immaterial principle that gives rise to the mental phenomena. We see it only in its results, which are, in many cases, as unequivocal as those produced by the agents referred to. All, perhaps, that we are justified in concluding is—with Dr. Good—"that instinct is the operation of the principle of organized life, by the exercise of certain *natural* powers, directed to the present or future good of the individual, whilst reason is the operation of the principle of intellectual life, by the exercise of certain *acquired* powers directed to the same object;—that the former appertains to the whole organized mass as gravitation does to the whole unorganized; equally actuating alike the smallest and the largest portions; the minutest particles and the bulkiest systems; and every organ, and every part of every organ, whether solid or fluid, so long as it continues alive;—that, like gravitation, it exhibits, under particular circumstances, different modifications, different powers, and different effects; but that, like gravitation, too, it is subject to its own division of laws, to which, under definite circumstances, it adheres without the smallest deviation; and that its sole and uniform aim, whether acting generally or locally, is that of perfection, preservation, or reproduction."[1]

In this view, *reason* demands discipline, and attains maturity: *instinct*, on the contrary, neither requires the one, nor is capable of attaining the other. It is mature from the first, and equally so in the infant as in the adult.[2]

The great cause of those mysterious phenomena, that characterize living bodies, and distinguish them by such broad lines of demarcation from the dead, has been a theme of anxious inquiry in all ages; and has ever ended in the supposition of some special abstract force, to which the epithet *vital* has been assigned, and which has received various appellations. Hippocrates designated it by the terms φυσις, and

[1] See an interesting chapter on Instincts and Habits in [Sir] Henry Holland. Chapters on Mental Physiology, p. 200, London, 1852. [2] Op. cit., p. 155.

ενορμων; Aristotle styled it the *animating* or *motive and generative principle;* Van Helmont, *archæus;* Stahl, *anima;* Barthez, and Hunter, *vital principle*, &c. &c. Yet, as Dr. Barclay[1] has observed, all physiological writers—ancient and modern—seem to be agreed, that the causes of life and organization are utterly invisible, whether they pass under the name of *animating principles*, (Aristotle, Harvey, &c.,) *vital principles*, (Barthez,) *indivisible atoms*, *spermatic powers*, *organic particles* or *organic germs*, (Buffon,) *formative appetencies* or *formative propensities*, (Darwin,) *formative forces*, (Needham,) *formative nisus* or Bildungstrieb, (Blumenbach,) *pre-existing monads*, (Leibnitz,) *semina rerum*, (Lucretius.) *plastic natures*, (Cudworth), *occult qualities*, or certain unknown chemical affinities. "All seem agreed, that whatever they be, they have been operating since the world began, and throughout the world operating regularly, without intermission, in various places at the same time. All seem agreed, that their modes of operation are strictly methodical; that they seem to act on definite plans, and actually exhibit specific varieties of chemical combination, and mechanical structure, which human intelligence cannot comprehend, much less explain. From their mutual dependence and other relations subsisting between them, all seem to speak as if they were subject to one great cause, which regulates and harmonizes the whole. All seem to speak of this great cause as if it were eternal, omnipotent, omnipresent; whether it be the element of fire, of air, or of water, or whether it be fate, nature, necessity, or a God."

By virtue of this principle or force of life,—the *biod* of Baron von Reichenbach[2]—every organized tissue is possessed of certain *properties*, to which the term *vital* has been assigned. Regarding the precise number of these properties, physiologists are not agreed. Whilst some have reckoned many; others have admitted but one. All the functions, which we have hitherto considered, are under the influence of life, and are products of the vital properties seated in the tissues; but we do not consider them to be directly caused by these properties. Digestion, for example, is executed by a series of organs, all of which are conducive to a certain result,—the aggregate constituting the function of digestion. The result of the action of the salivary gland is very different from that of the liver; yet both operations are vital, but modified by the different organization of the two glands. We do not ascribe the difference to a difference in the vital properties of the glands. These are probably the same in both; and are seated in the primary tissues, of which all the more compound textures and organs are built up. They are primary or fundamental properties of living matter.

Stahl, having observed obscure, oscillatory movements, alternate contraction and expansion in certain parts of the body, either during the exercise of a function, or on the application of some external agent, conceived, that every part of the frame is, at all times, more or less susceptible of similar movements. These movements he called *tonic;*

[1] An inquiry into the Opinions, ancient and modern, concerning Life and Organization, p. 519, Edinb., 1822; and The Muscular Motions of the Human Body, p. 261, Edinb., 1808.

[2] Physico-Physiological Researches on the Dynamics of Magnetism, Electricity, Heat, Light, Crystallization, and Chemism in their relations to vital force, English edit. by Dr. Ashburner, p. 224, Lond., 1850.

their effect upon the organs *tone*, and the property by which they were induced he esteemed peculiar to organization, and called *tonicity*. This vital property, he conceived, influences the progression of the fluids in the vessels; the phenomena of exhalation and absorption; and is totally distinct from the properties possessed by inorganic bodies.

Haller[1] admitted two vital properties, very different from each other, which seemed to him to be equally elementary. By the one of these a living part exhibits itself to be *sensible*, or transmits to the sensorium an impression made upon it either by an extraneous body, or by its own internal and organic action; by the other, a part contracts in a manner appreciable to the senses, either by the influence of the will, or of some external or internal stimulus. The first of these he considered to be a special vital property, which he termed *sensibility;* and the second to be another, which he called *irritability*. Prior to his time the word irritability had been adopted by Glisson,[2] who had noticed the fact that living matter is acted upon by *irritants* of various kinds in a mode no wise analogous to physical and chemical motions; and hence he concluded, that every organ of the human frame possesses an inherent and peculiar force, which presides over its movements, and is requisite for the exercise of its functions. This force he called *irritability*. De Gorter[3] subsequently extended the views of Glisson, and applied them to the vegetable, affirming irritability to be the sole vital property of all organized bodies, vegetable as well as animal. The acceptation, given to the term by Haller, was consequently more limited. He restricted it to those motions of parts that fall under the observation of the senses;—such as the contraction of the voluntary muscles, heart, &c. He made numerous experiments on living animals, for the purpose of discovering what parts are possessed, and what are not, of the true properties of *sensibility* or *irritability*, and he concluded, that the former resides exclusively in the nervous,—the latter in the muscular, system. Dr. Marshall Hall[4] still employs the term in the restricted sense of Haller.

This celebrated theory, which formed so large a part of physiological science at one time, and is still an interesting topic to the physiologist, has been referred to in so many parts of this work as to require but few comments here. We have seen, that many parts, regarded by Haller as insensible, are acutely sensible in disease; and that we cannot pronounce a part to be positively insensible, until we have applied every kind of irritant to it without effect. We have elsewhere defined sensibility to be an exclusive property of the nervous system; and have attempted to show, that irritability is a property of the muscular tissue—a *vis insita*—totally independent of the nerves, but of which the nervous fluid is an appropriate excitant. As, however, the vital properties of sensibility and irritability were restricted by Haller to the nervous and muscular systems, they were regarded to be insufficient for the explanation of the various living actions of the frame: the

[1] Element. Physiol.; and Mémoire sur la Nature Sensible et Irritable des Parties du Corps, Lausan., 1756.

[2] De Ventriculo, in Manget. Bibl. Anatom., i. 80, Genev., 1699.

[3] Medicin. Compendium, Lugd. Bat., 1742.

[4] Art. Irritability, Cyclop. of Anat. and Physiol., July, 1840.

next step was to extend them to every part and to every tissue. It was found, for example, that on investigating the most minute movements of parts, these movements were always preceded by an impression, to which they seemed sensible, and which appeared to excite their actions. This general property, common to every living part, of receiving an impression, was called *sensibility*;—thus generalizing the property, which Haller had restricted to perceptivity by the mind. Every part was said to be *sensible* to the blood sent to it for its nutrition. Again, every part was observed to move in consequence of the impression it received, sometimes in an apparent manner, as the heart; at others, too slightly for its movements to be recognized otherwise than by the results,—as in the case of the glandular organs; but always in a manner special to organized matter, and not analogous to any physical or chemical process. This motion was, therefore, referred to another force called *motility*, which was nothing more than irritability generalized. These two properties are alone admitted by most modern writers. Every organ is said to *feel* and to *move*, after its manner, in the performance of its function;—the stomach in digestion; the heart in propelling the blood; the muscle in contracting, and the nerve in transmitting sensitive impressions to the brain.

Many modern physiologists, whilst they admit the vital properties of sensibility and motility, have reckoned a greater number: this is owing to their having observed, that each part has its own peculiar mode of sensibility and motility; and when these modes have seemed to differ largely from each other, they have elevated them into so many special vital properties. The chief modern theories on the vital properties are those of Barthez, Blumenbach, Chaussier, Dumas, and Bichat. M. Barthez[1] admitted five, which we can do no more than enumerate,—*sensibility*, *force of contraction*, *force of expansion* or *active dilatation*, *force of fixed situation*, and *tonicity*. Blumenbach[2] also admitted five;—*sensibility*, *irritability*, *contractility*, *vita propria* or *proper force of life*, *nisus formativus*—*force of formation* or B i l d u n g s t r i e b. M. Dumas[3] referred all the living phenomena to four vital properties; *sensibility*, *motility*, *force of assimilation*, and *force of vital resistance*. The theory of Bichat[4] on this subject requires a more detailed notice. He, also, admitted five vital properties; *organic sensibility*, *insensible organic contractility*, *sensible organic contractility*, *animal sensibility*, and *animal contractility*. *First. Organic sensibility* is the faculty possessed by every living fibre of receiving an impression, or of being modified by contact, the modification being restricted to the part that experiences it, and not transmitted to the brain. The term *sensibility* was adopted by Bichat because already established: and the epithet *organic* was added to affirm, that it is the exclusive attribute of organized bodies, and common to all. This property is not only modified in each organ—as the difference in their nutrition and functions demonstrates—but it adapts each organ to its appropriate external excitant, so that the sali-

[1] Nouveaux Élémens de la Science de l'Homme, Paris, 1806.
[2] Institutiones Physiologicæ, Gotting., 1786; or Elliotson's translation.
[3] Principes de Physiologie, 2de édit., Paris, 1806.
[4] Anatomie Générale, tom. i.; and Recherches Physiologiques sur la Vie et la Mort, Paris, 1800.

vary gland shall be specially influenced by mercury; the upper part of the small intestine by calomel; the lower by aloes, &c. &c. Its exercise is continuous, involuntary, known only by its results, and is more marked as we descend in the scale of animal life; whilst animal sensibility is the contrary. *Secondly. Insensible organic contractility* is the faculty possessed by every living part, of moving in an imperceptible manner, in consequence of an impression immediately received, without either the mind having consciousness of the motion, the will participating, or the brain in any manner directing it. We have an example of this in the action of the stomach during digestion; and of every part of the body on the blood sent to it for its nutrition. Bichat applied the term *insensible organic contractility* to this property, for the following reasons:—*contractility*, because contraction is the kind of motion which constitutes it; *organic*, because it is common to all living beings; and *insensible*, because the brain has no consciousness of it. Like organic sensibility, it is modified in each organ. Its exercise is likewise continuous and involuntary; and it also exhibits itself more intensely as we descend the scale of beings. It always co-exists with organic sensibility. *Thirdly. Sensible organic contractility* is the same motive faculty as the last, with this difference, that the movements induced by it fall under the senses, and are recognized independently of their results. This property is likewise modified in each organ; its exercise is also involuntary, and it only differs from the last in degree,—the movement that constitutes it being apparent. Thus, the heart contracts independently of the will, but its motions are not imperceptible, as in the cases which belong to the second vital property—insensible organic contractility. *Fourthly. Animal sensibility* is the property possessed by certain organs of transmitting to the mind, through the medium of the brain, the consciousness of impressions, which they have received. It is sensibility in the restricted acceptation of Haller. The epithet *animal* was given to it by Bichat, to distinguish it from the other variety of sensibility, which belongs to all organized bodies, whilst this is exclusively possessed by animals. The whole of the attributes of this property have been detailed at much length in another portion of this work. *Fifthly.* Bichat admitted a fifth vital property, under the name *animal contractility*, which comprised voluntary muscular contraction;—treated of elsewhere in this volume, as one of the functions of the body. It differs from organic contractility in its exciting causes not being seated in the organ in which it is developed,—that is, in the muscles,—but in the brain; and, moreover, whilst other varieties of contractility are irresistibly connected with, and proportioned to, the kind of sensibility correspondent to them, such is not the case with animal sensibility, and its play is never continuous.

From the distinction we have endeavoured to draw between the fundamental vital properties and the functions, it will be obvious that the ingenious division of Bichat is susceptible of farther curtailment by analysis. A vital property must be one possessed by all living bodies; it is fundamental in the tissues, and differs according to the precise structure of the tissue. It is found in the vegetable as well as in the animal. Neither of the last two properties of Bichat, however, corresponds with this definition. They do not exist in the vegetable. They

require not only a nervous system, but a brain, that can conceive and will. They are both, indeed, complicated functions, and, as such, have been considered at great length elsewhere. By ultimate analysis, therefore, the five vital properties of Bichat may be reduced to two,—*sensibility* and *motility*. Perhaps we ought to rest satisfied with the admission, that every primary tissue is capable of being acted upon by appropriate stimuli or is *sensible;* and that it possesses the additional property of *moving* in consequence of such impression. Physiologists have, however, attempted to simplify the subject still farther, and to reduce the vital properties to one only. Such is the view of M. Broussais, who considers *contractility* to be the fundamental vital property of all the tissues. Adelon considers, that *sensibility*, which must carry with it the idea of motion, and is the active, motive faculty of living matter, is the only living property that should be admitted. The term *sensibility* is not, however, unexceptionable, in consequence of its being often used exclusively to convey the notion of mental or conscious perception, and of such acceptation having been received into physiology to designate a function. It has, consequently, been proposed to substitute the term *excitability*, *incitability* or *irritability*, but with the same signification. Rudolphi[1] prefers *incitability*, (Erregbarkeit,) as not liable to the objection that may be urged against the others, of having been employed in other significations. This incitability differs in the different organs and tissues; in the muscles he terms it *irritability* (Muskelkraft, Reizbarkeit); in the nerves, *sensibility* (Nervenkraft, Empfindlichkeit); and by some physiologists, in the membranous parts, it is called *contractility* (Spannkraft, Zusammenziehungskraft).

It has generally been considered, that the cessation of irritability in a tissue indicates its positive death; yet experiments have sufficiently shown, that the vital property can be restored. Dr. Kay[2] had found, that if blood be injected into the vessels of a dead animal, immediately after irritability has disappeared, the vital property will re-appear. Dr. Brown-Séquard[3] has shown, that in this way the vital property of nerves and muscles may be restored in limbs which have lost their irritability and been rigid even for hours. He tied the aorta immediately behind the origin of the renal arteries in several rabbits. Shortly afterwards, sensibility and the voluntary movements disappeared in the posterior limbs. He waited until muscular irritability had given way to cadaveric rigidity, and when this had lasted twenty minutes, he relaxed the ligature; circulation took place, and sensibility and voluntary movements re-appeared. Hence he infers, that not only local life, but all the properties and actions of full life can be restored in limbs that have been in the state called *rigor mortis*, *cadaveric* or *post-mortem rigidity*.

The conclusions of Dr. Brown-Séquard, from all his experiments on the subject on decapitated men and animals, are:—that *first*, red blood, that is, richly oxygenated blood (arterial or venous) is able to revive

[1] Grundriss der Physiologie, 1er Band., S. 247, Berlin, 1821.
[2] The Physiology, Pathology and Treatment of Asphyxia, p. 143, London, 1834.
[3] Medical Examiner, May, 1853, p. 280.

irritability in muscles, four or five hours after these organs have lost their property. *Secondly.* Red blood is able to revive the vital properties of nerves and nervous centres, when these properties have not been lost for more than about an hour. *Thirdly.* Muscular irritability can be maintained for more than forty-one hours, by mere injections of blood, in limbs separated from the body of a rabbit.

Such are the phenomena that indicate the existence of a vital force, and such the laws by which it seems to be governed. By certain physiologists it is considered to influence solids only: by others, it has been considered to reside in the fluids also, and especially in the blood. The notion of the vitality of this fluid was espoused by John Hunter,[1] and to him we are indebted for many of the facts and arguments brought forward in its favour, which have impelled the generality of modern physiologists to admit its existence. The analogy of the egg had demonstrated that life is not restricted to substances which are solid and visibly organized. The fresh egg, like other living bodies, possesses the ordinary counteracting powers communicated by vitality, and resists those agents that act on the dead egg as on other animal substances deprived of the living influence. The fresh egg may be exposed for weeks, with impunity, to a degree of heat that would inevitably occasion the putrefaction of the dead egg. During the time of incubation, the egg of the hen is kept for three weeks at a heat of 105°; yet when the chick is hatched, the remaining yolk is perfectly sweet. The power of resisting cold is equally great. Dr. Hunter performed several experiments, which show the influence of the vital force in resisting cold, and of cold in diminishing the energy of the force. He exposed an egg to the temperature of 17° and 15° of Fahrenheit, and found that it took about half an hour to freeze. When thawed, and again exposed to a temperature of 25°, it was frozen in one-half the time. He then put a fresh egg, and one that had previously been frozen and again thawed, into a cold mixture at 15°; the dead egg was frozen twenty-five minutes sooner than the fresh.[2] These experiments led to the legitimate inference, that the former possessed the force of life, and, although fluid, must have enjoyed the properties which we have described to be characteristic of vitality,—of being acted upon by an appropriate irritant, and of moving responsive to the irritation. Similar results to those obtained with the egg followed analogous experiments with the blood. On ascertaining the degree of cold, and the length of time necessary to freeze blood taken immediately from the vessel, he found that, as in the egg, a much shorter period, and a much less degree of cold, were requisite to freeze blood that had been previously frozen and thawed, than blood recently taken from the vessel. The inference deduced from this was, that the vitality of recent blood being comparatively unimpaired, it was enabled to resist cold longer than blood whose vital energy had already been partly exhausted by previous exposure. It would appear, however, that the vital force in fish can resist the action of frost. Those that were caught by Captain Franklin's party in Winter Lake froze as they were taken out of the

[1] Treatise on the Blood, &c., p. i., ch. i.
[2] Philosoph. Transact., 1778, pp. 29, 30.

nets, and became in a short time a solid mass of ice; yet when thawed they were alive.[1]

The fluidity of the blood whilst circulating in the vessels has been regarded as an additional evidence of its vitality. It is obvious, that such fluidity is indispensable, seeing that it has to circulate through the minute vessels of the capillary system, and that the slightest coagulum forming in them would lead to morbid derangement. Yet the blood is, by its constitution, peculiarly liable to become solid, and whenever it is removed from its vessels it coagulates. This is not owing simply to the cessation of circulation, for if it be kept at the same temperature as in the living body, and be made to circulate with equal rapidity through a dead tube, it equally becomes solid. The cause, consequently, that maintains its fluidity, is the vital agency; or, as J. Müller remarks, the proper combination of its elements is maintained so long only as it is under the influence of living surfaces,—that is, of the vessels. The experiments of Schröder van der Kolk[2] show, that coagulation takes place with extraordinary rapidity after the brain and spinal marrow have been broken down; even in a few minutes after the operation, coagula were found in the great vessels. Mayer observed, that after the application of a ligature to the pneumogastric nerve the blood coagulated in the vessels, and death was produced. Sir Astley Cooper, on repeating the experiment, found, that the conversion of venous into arterial blood in the lungs was prevented. Of four experiments, however, which were performed under the direction of J. Müller,[3]—two on dogs and two on rabbits,—although the animals were examined immediately after death, which resulted from the ligature of the pneumogastrics, in two cases only was a small coagulum, of the size of a pea, discovered in the left side of the heart, and none in the pulmonary vessels. Another argument in favour of the vitality of the blood is drawn from the facts connected with its coagulation,—facts which show that the process is but little influenced by physical agents, and which have induced M. Magendie[4] to infer, with many other physiologists, who are but little disposed to invoke the vital agency, "that the coagulation of the blood cannot be ascribed to any physical influence, but must be esteemed essentially vital, and as affording a demonstrative proof, that the blood is endowed with life." It has, indeed, been attempted to show, that there are certain phenomena, which demonstrate that the vitality of this fluid increases or diminishes with the vitality of other parts of the body. When blood is drawn from a vessel it does not instantly coagulate or die; and, by observing the length of time consumed in the process, it has been thought that we might, in some measure, be able to estimate the degree of vital energy it possesses. In diseases where the vital action is exalted,—as in inflammation,—the blood is found to coagulate more slowly than in a state of health, and the coagulation

[1] See page 595 of the first volume.

[2] Comment. de Sanguin. Coagulat., Groning., 1820; and Diss. sist. Sanguin. Coagulat., Groning., 1820, cited in Müller, Handbuch u. s. w., Baly's translation, p. 97, Lond., 1838.

[3] Op. cit., p. 98.

[4] Précis de Physiologie, 2de édit., ii. 234, Paris, 1825.

itself is more perfect, whilst in those that are dependent upon a diminution of the vital energy, the opposite is the fact; because, in the first case, it is presumed, the blood possesses the vital force in a higher degree than natural, and consequently resists, for a longer period, the influence of the physical agents to which it is exposed; whilst, in the second case, it possesses the vital force to a less degree than natural, and therefore yields sooner to the influence of those agents,—the coagulation, in all instances, being analogous to the rigidity of the muscles which takes place after dissolution, and has been conceived to indicate the final cessation of vitality or the last act of life.[1]

The buffy coat or inflammatory crust of the blood, called, also, *corium phlogisticum* and *crusta pleuretica*—the nature of which has been already investigated (vol. i. p. 379),—is a circumstance connected with the blood's presumed life, that has been invoked by the supporters of this view of the subject. These terms are applied to an appearance of the crassamentum, which is dependent upon its upper portion containing no red particles, but exhibiting a layer of a buff-coloured coriaceous substance lying at the top, owing to the red corpuscles, during coagulation, sinking to the lower portion of the clot, before coagulation is completed; hence, the colourless state of the upper surface. At the same time, the whole of the coagulated portion is generally much firmer than usual. The red corpuscles, in such case, have time to subside before the coagulation is complete, which takes place more slowly than in health; which is conceived to be owing to the blood's possessing a higher degree of vitality,—a view confirmed by some experiments of Mr. Thackrah.[2] These consisted in receiving blood, taken from the vessels of a living animal in a full and uninterrupted stream, into different cups, and noting the time at which coagulation commenced in each. Blood, for example, was taken from a horse at four periods, about a minute and a half being allowed to intervene between the filling of each cup. In the first cup, coagulation began in eleven minutes and ten seconds; in the second cup, in ten minutes and four seconds; in the third cup, in nine minutes and thirty-five seconds; and in the fourth cup, in three minutes and twenty seconds. In another experiment, blood was drawn into three separate cups from the veins of a slaughtered ox, the first of which was filled in the first flow; the second, about three minutes afterwards; and the third, a short time before the death of the animal. Coagulation commenced, in the first cup, in two minutes and thirty seconds; in the second, in one minute and thirty-five seconds; and in the third, in one minute and ten seconds. In a similar experiment, it commenced in the first cup, in two minutes and ten seconds; in the second in one minute and forty-five seconds; and in the third, in thirty-five seconds. Similar phenomena are found to occur in the human subject. Blood, to the amount of about a pint and a half, was taken from the arm of a female labouring under fever. A portion of this, received into a cup on its first effusion, remained fluid

[1] See, on the Evidences of the Life of the Blood, from its self-motion, p. 432 of the first volume.

[2] An Inquiry into the Nature and Properties of the Blood, in Health and in Disease, Lond., 1819.

seven minutes; a similar quantity, taken immediately before tying up the arm, was coagulated in three minutes and thirty seconds. Of blood, taken as in the last experiment from the arm of a man, the first portion began to coagulate in seven minutes; the last in four. It has been conceived, that the vitality of the system, and with it that of the blood, being diminished by each successive abstraction, it coagulated or died sooner and sooner in proportion as it was previously more and more enfeebled. It is proper to observe, however, that the blood may remain fluid in the vessels, and coagulate when removed from them, long after the death of the body. In a case observed by the author, it flowed freely from the vessels of the brain and coagulated fifteen hours after the total cessation of respiration and circulation;[1] and many such cases have been observed by others.[2] They would seem to show, that the phenomenon of coagulation is wholly physical in its nature, and not the last act of its vitality, as is held by some.[3] It is affirmed by M. Buisson,[4] that the same fact has been observed in regard to the chyle. In one case it was fluid in a man twenty-four hours after death, but soon coagulated after its escape from the vessels. "Mr. Hunter" —says Mr. Gulliver[5]—"conceiving coagulation to be an act of life, maintained that the blood coagulates by virtue of its living principle. If we admit this hypothesis, we must also admit that we can pickle the life; that it is preserved after repeated freezing and thawing; and, as Dr. Davy remarks, that the blood may remain alive many hours after the death of the body, when the muscular fibre has lost its irritability, the limbs have stiffened, and even partial decomposition has begun. Besides, a mixture of two varieties of perfectly clear serum will coagulate spontaneously, as I have witnessed upon filtering them four days after they were drawn from the living human body; and M. Denis states, that fibrin may be dried and powdered, and yet possess the power of self-coagulation when dissolved in a neutral salt, and diluted with water.

The late Professor Harrison, of New Orleans,[6] who was properly chary in ascribing to vital influence what may admit of a physical or chemical explanation, expresses the opinion "that we must expect from chemistry the solution of the mystery of the change of form that takes place as well during the coagulation of the blood, as in other cases in the existing state of knowledge inexplicable;" and he instances the spontaneous change of form from fluid to solid that takes place in cyanic acid from no known cause; as well as in chloral and aldehyde. The change of form that occurs in the last substance, he considers to be

[1] Proceedings of the American Philosophical Society, for May, June and July, 1840, p. 216; and Amer. Med. Intelligencer, Aug., 1840.

[2] The fact was repeatedly noticed by Professor S. Jackson in the bodies of those who died in Philadelphia of the yellow fever of 1820. See J. Davy, Researches, Physiological and Anatomical, ii. 190, Lond., 1839; or Dunglison's Amer. Med. Lib. edit., Philad., 1840. A case has been given by Dr. Polli, in which the blood did not coagulate completely till fifteen days after it was drawn, in Gazette Medica di Milano, 20 Gennaio, 1844, cited by Mr. Paget, in Brit. and Foreign Med. Rev., Jan., 1845, p. 253.

[3] Carpenter, Principles of Human Physiology, Amer. edit., p. 208, Lond., 1855.

[4] Gazette Médicale de Paris, 29 Juin, 3 and 17 Août, &c., 1844.

[5] Note to Hewson's works, Sydenham Society's Edit., p. 21, Lond., 1846.

[6] New Orleans Medical and Surgical Journal, July, 1847, p. 46.

"even more singular than that which occurs in the fibrin of the blood, and equally inexplicable in the present state of science." "As well," —he adds—"might we invent some *principle* to account for the transformations of aldehyde as for those of fibrin."

It is manifest, then, that if it be granted that some of the above and other arguments lead to a belief in the vitality of the blood, they are equally favourable,—many of them at least,—to the vitality of the chyle, which—we have seen—closely resembles the blood in its properties, except in that of coloration; and if we admit the blood to be possessed of life, a question arises, respecting the part at which the nutritive substances, taken into the system, become converted into the nature of the being they are destined to nourish, and receive the vital force. This must be either through the admixture of the fluids poured out from the supra-diaphragmatic portion of the alimentary canal, or from those of the stomach or small intestine; or owing to the mysterious and inappreciable agency of the chyliferous radicles themselves, which separate the same fluid, chyle, from every substance, that may be submitted to their action. A reference to what has been said on these topics, under the heads of DIGESTION and ABSORPTION, would lead to the opinion, that no vitalizing influence is exerted on the food in the stomach and intestines; and therefore, that the infusion of vitality—if the expression may be allowed—would have to take place in the chyliferous vessels. As to the mode in which the blood becomes vitalized—if possessed of vitality—great doubt must necessarily exist. The general opinion, perhaps, is, that it is made so by the organic nerves distributed to the inner coats of the vessels; and this idea was considered to be confirmed by an experiment of the late Mr. Thackrah, which showed, that blood, received into a dead vessel, is always more speedily coagulated than when it is retained by ligature in a living vessel; whence he inferred, that the vitality of the vessels affects the blood; and retards its coagulation. Mr. Thackrah denies, indeed, the life of the blood, and ascribes all the evidences which it exhibits of life, to the influence exerted by the living vessels on their contents.

On the whole, then, we are led to the conclusion, that the doctrine, which maintains, that the blood is a living fluid is by no means established, and that facts and arguments are more in favour of the view, that in the bloodvessels fluid is contained, and distributed over the body, which serves as the pabulum from which every part of the organism is formed; but that the real plastic or organizing power is seated in the cells which constitute the various tissues; and it is necessary for appropriate materials to leave the vessels, and come in contact with them in order that organized tissue shall result from their elaborating agency.

CHAPTER VI.

DEATH.

It has wisely entered into the views of Providence, that the existence of all organized bodies should be temporary; yet we find considerable difference amongst them in this respect. Whilst some of the lower classes of animals and vegetables are no sooner ushered into being than a process of decay appears to commence; others require the lapse of ages for their developement and declension; and, as a general rule, those, in which the attainment of growth has been slow, have the period of decrease proportionably postponed; whilst, where maturity has been rapidly attained, decay as rapidly supervenes.

It has been elsewhere shown, that each part of the body, as regards the cells that compose it, may be considered to have a life of its own, —a cell life: hence, a minute part may die and be reproduced without the general life of the individual suffering; and in certain of the lower animals, so little is the organism affected by injuries of a part, that when the animal is cut in pieces, each piece may undergo a distinct developement, so as to form as many separate beings. In the higher animals, however, this is not the case. In them, the death and reproduction of every part of the frame are taking place in the function of nutrition; and it is only when organs, that are intimately associated with each other, and whose association is essential to the life of the whole, have their functions interrupted, that the cessation of other functions, and general death, follow. The death that takes place in minute parts has been called *molecular;* that of the whole body *somatic.*

The ages of man are numerous and protracted. For a time, the parts of the frame concerned in his developement unceasingly deposit the necessary particles, by a process as beautiful and as systematic as it is mysterious; until ultimately the growth peculiar to the species and the individual is attained. At this point, the preponderance, that previously existed in the action of the organs of composition over those of decomposition appears to cease. All is equality; but, ere long, the former flag in their wonted activity; the fluids decrease in quantity; the solids become more rigid; and all those changes supervene, which we have described as characterizing the decline of life, and the approach of the phenomena that have now to be considered.

Death is the necessary, total, and permanent cessation of those functions by which life is characterized. This cessation may happen at all ages from accident or disease; a few only cease gradually to live through the effects of age alone. Hence, a distinction has been made into that kind of death, which is produced by the gradual wear and tear of the organs, and that which cuts off the being prematurely from existence. The former has been termed, by some physiologists, *senile* or *natural;* the latter *accidental.* These differ considerably in their physiology; and will, therefore, require a distinct consideration.

1. DEATH FROM OLD AGE.

The *natural period of life* is different in different individuals. It varies according to numerous appreciable and inappreciable circumstances;—the original constitution of the individual; habits of life; the locality in which he may reside, &c. Whilst some countries are remarkable for the longevity of their inhabitants; others surprise us by the short period allotted for the natural duration of life. Blumenbach asserts, that by an accurate examination of numerous bills of mortality, he ascertained the fact, that a considerable portion of Europeans reach their 84th year, but that few exceed it; whilst, according to M. Foderé,[1] in the insalubrious region of Brenne, in France, nature begins to retrograde at from 20 to 30; and 50 years is the usual term of existence. Haller[2] noted one thousand cases of centenarians; sixty-two of from 110 to 120 years; twenty-nine of from 120 to 130; and fifteen who had attained from 130 to 140 years. Beyond this advanced age, examples of longevity are much more rare, and less sufficiently attested; yet we have some well authenticated cases of the kind. Thomas Parr, who died in 1635, married at the age of 120, retained his vigour till 140, and died at the age of 152, from plethora—it was supposed—induced by change of diet. Harvey dissected him, and found no appearance of decay in any organ.[3] Henry Jenkins, who died in Yorkshire, in 1670, is an authentic instance of the greatest longevity on record. He lived 169 years.

The following list of instances of very advanced age has been given.[4]

	Lived.	Age.
Apollonius of Tyana,	A. D. 99	130
St. Patrick,	491	122
Attila,	500	124
Llywarch Hên,	500	150
St. Coemgene,	618	120
Piastus, King of Poland,	861	120
Thomas Parr,	1635	152
Henry Jenkins,	1670	169
Countess of Desmond,	1612	145
Thomas Damme,	1648	154
Peter Torton,	1724	185
Margaret Patton,	1739	137
John Roven and Wife,	1741	172 and 164.
St. Mongah or Kentigen,	1781	185

It would not seem that the natural period of life has differed much in postdiluvian periods. The Psalmist writes:—

> "The days of our years are threescore years and ten; and if by reason of strength they be fourscore years, yet is their strength labour and sorrow, for it is soon cut off, and we fly away."[5]

And when Barzillai excused himself for not visiting the royal palace at Jerusalem, he observed to the king:—

[1] Traité de Médecine Légale et d'Hygiène Publique, tom. v. p. 537, Paris, 1813.
[2] Element. Physiol., xxx. 3.
[3] Philos. Transact., vol. iii. 1699.
[4] Prichard, Researches into the Physical History of Mankind, 2d edit., i. 421, London, 1836.
[5] Psalm xc.

"I am this day fourscore years old, and can I discern between good and evil? can thy servant taste what I eat or what I drink? can I hear any more the voice of singing men or singing women? wherefore then should thy servant be yet a burden unto my lord the king?"[1]

Buffon affirmed, that the natural period of life, where death does not occur from accident, or disease, is ninety or one hundred years; and M. Flourens,[2] who argues that, as everything in the economy is subjected to fixed laws, and therefore, that the natural term of life must be likewise, reckons it at one hundred years. Buffon suggested, that the natural period might be estimated from the period of full growth, which, in man, he places at 14 years. Six or seven times the period of growth, according to him, would give the natural period of life. M. Flourens, whilst he adopts this mode of reckoning, says that one single thing was wanting in the estimate of Buffon—a certain sign to mark the term of growth. This, he says, is found in the union of the bones with their epiphyses, which, as elsewhere remarked, he fixes at 20 years. "Man is 20 years in attaining full growth, and he lives five times 20 years, or 100; the camel grows 8 years, and it lives five times 8, or 40 years; the horse grows 5 years, and it lives five times 5 years, or 25 years; and so of other animals." The real ratio, according to him, is therefore nearly five times, in place of six or seven, as supposed by Buffon.[3]

The census of the United States has strikingly exhibited the influence of races on longevity in the same country. In 1830, according to Professor Tucker,[4] the proportion of whites over 100 years of age, was 1 in 19,529; of free coloured, 1 in 487; and of slaves, 1 in 1410. The census of 1840 confirms this immense difference,—the whites over 100 were in the proportion of 1 in 17,938; the free coloured of 1 in 597; and the slaves of 1 in 1,866. The preponderance of cases of extreme longevity in the coloured classes, and in the free coloured over the slaves, is likewise seen in the census of 1850; but, in both, it is less than in the censuses of 1830 and 1840. In all the censuses, the ratio of advanced age of females is greater until it exceeds 100 years, when the males have the advantage.[5] It is stated by Tschudi,[6] that the Peruvian Indians are remarkable for longevity, although they frequently shorten their lives by the intemperate use of strong drinks. Instances, he says, are not rare of their living to 120 or 130 years of age, retaining full possession of their bodily and mental powers.

It is not easy to indicate the character of organization most conducive to longevity and to health. Much must depend on the habits of the individual, and the degree of toil and exposure to which he has been subjected; and this may partly, if not wholly, account for the greater longevity of women, which in England, as well as in this country,—as far as observation has been made,—is decided. Of four-

[1] 2 Samuel, xix. 35.
[2] De la Longévité Humaine et de la Quantité de Vie sur le Globe, 2de édit., p. 78, Paris, 1855.
[3] Flourens, op. cit., p. 94.
[4] Progress of the United States in Population and Wealth in Fifty Years, as exhibited by the Decennial Census, p. 72, New York, 1843.
[5] Professor Tucker, Appendix to the same, p. 23, New York, 1855.
[6] Travels in Peru during the years 1838–1842, translated by Thomasina Ross, p. 339, New York, 1847.

teen persons in the Philadelphia Hospital, during a period of twelve years,[1] who lived beyond one hundred years, but five were men; and the only two who exceeded 110 were women, one of whom reached her 119th year, and died of cholera in 1832. There is difficulty, however, in arriving at exact results as regards these extreme ages. Accurate records are but rarely kept; and much of the evidence is altogether traditional. This is strikingly the case in regard to the coloured races, and has impressed all statisticians in regard to the whites, also. In Great Britain, it was estimated, that of the twenty-one millions of inhabitants in the year 1851, more than half a million—596,030—had exceeded the three-score years and ten; more than one hundred and twenty-nine thousand had passed the "fourscore years;" nearly ten thousand had lived 90 years or more; two thousand, 95 years and more; and three hundred and nineteen affirmed, that they had witnessed more than a hundred anniversaries. One hundred and eleven men, and two hundred and eight women, were returned of ages varying from 100 to 119 years. "Two-thirds of the centenarians"—say the reporters on the census[2]—"are women. Several of them, in England, are natives of parishes in Ireland or Scotland, where no efficient system of registration exists; few of them reside in the parishes where they were born, and have been known from youth; many of the old people are paupers, and probably illiterate; so that it would no doubt be difficult to obtain the documentary evidence, which can alone be accepted as conclusive proof of such extraordinary ages. Until the system of registration, and the census, have been for many years in operation, the evidence of extreme ages must remain indecisive; but there can be now no doubt that some of the twenty-one millions of people in Great Britain have lived a century; which may therefore be considered the circuit of time in which human life goes through all the phases of its evolution."

It has been generally considered, that the proportion of deaths to the population in any community may be regarded as an exponent of the *average duration of life* in that community;—that if, for example, in Philadelphia 1 in 45 dies yearly, the average age of all who die will be 45. So far as the estimates made of the number of people before any census was taken may be depended upon, it would appear, according to Mr. Chadwick,[3] that the ratio of deaths in London to the population was, at the commencement of the last century, 1 in 20. At the time the first census was taken—in 1801—the ratio, within the bills of mortality, was 1 in 39. In 1843, it appeared to be 1 in 40. Having had the average ages of death within the bills of mortality calculated from the earliest to the later published returns, he found them, as far as they could be made out from the returns, which are only given in quinquennial and decennial periods, to be as follows:—

	Average age.
22 years, from 1728 to 1749,	25 years, 1 month.
25 years, from 1750 to 1774,	25 " 6 months.
25 years, from 1775 to 1799,	26 " 0 "
25 years, from 1800 to 1825,	29 " 0 "
6 years, from 1825 to 1830,	29 " 10 "

[1] Tabb, American Journal of the Medical Sciences, Oct., 1844, p. 373.
[2] The Census of Great Britain in 1851, &c. &c., p. 30, London, 1854.
[3] Report on the Practice of Interment in Towns, p. 241, London, 1843.

Whilst, consequently, it would appear, from the proportionate number of deaths to the population, that the average duration of life had doubled during the last century, the returns of the average ages show, that it had only increased about one-fifth. In one year the mortality may be greater amongst children, in another amongst the aged; so that whilst the proportion of deaths to the population may be the same, the average of the ages at which death occurs may differ materially.[1]

Generally, the aged individual sinks silently to death, totally unconscious of all that surrounds him, in the manner described under Decrepitude. At other times, he preserves his sensorial powers to the last, and may be capable of locomotion; until, owing to oppression or disturbance of action of one or other of the vital functions during sleep, it becomes the sleep of death,—the elasticity of the organs being insufficient to throw off the deranging influence and resume their functions. At other times, a slight febrile irritation is the prelude to dissolution.

The great characteristic of this kind of death—as pointed out by Bichat in one of the best of his excellent productions[2]—is, that animal life terminates long before organic life. Death takes place in detail,—the animal functions, which connect the aged with the objects around him being annihilated long before those that are concerned in his nutrition. Death, in other words, takes place from the circumference towards the centre, whilst in accidental or premature death, the annihilation of the functions begins in the centre and extends to the circumference. As vitality gradually recedes in the aged from the exterior, one of the great centres of vitality—brain, heart, or lungs—stops for an instant. The powers are insufficient to restore the action, and total death necessarily ensues.

It has been an interesting topic with physiologists to determine the cause of death thus naturally occurring. Opinions have varied, but such causes as affect the three great vital functions seem to be most entitled to consideration. These have been supposed to be:—*First*, ossification of the arteries, occasioning an obstacle to the free circulation of blood in the parts; *Secondly*, ossification of the cartilages of the ribs, and diminution of the capillary system of the lungs, preventing sanguification;—and *Thirdly*, shrivelling and gradual induration of the nervous system, rendering it ultimately unfit for innervation, &c. These are the physical circumstances or changes, that may give occasion to the final cessation of the vital phenomena; but, after all, the difficulty remains,—and it is insolvable,—to explain the cause why these changes themselves occur in the organs essential to vitality. We say it is insolvable, for, until we have learned the nature of life, which seems far beyond our comprehension in the present state of knowledge, it is obviously impracticable to understand the phenomena that arise from its gradual declension and final extinction. This kind of death, produced by the gradual declension of the powers of life, is regarded by Dr. W. Philip[3] as only the last sleep, characterized by no pecu-

[1] Fifth Annual Report of the Registrar-General, &c., London, 1843.

[2] Recherches Physiologiques sur la Vie et la Mort, Paris, 1800.

[3] Philosophical Transactions for 1834; and an Inquiry into the Nature of Sleep and Death, p. 166, London, 1834.

liarity, in which the powers, partly from their own decay, and partly from the lessened sensibility increasing the difficulty of restoring the sensitive system, become incapable of the office, and the individual, therefore, wakes no more. We have before remarked, that there appears to us to be a marked difference between sleep and death, although they may trend closely on the confines of each other. It is not common, however, for death to occur in this quiet and gradual manner. Man is liable to numerous diseases from the earliest to the latest period of existence, many of which are of a fatal character. It was admitted by Sydenham, whose estimate cannot be regarded as more than an approximation, that two-thirds of mankind die of acute diseases; and that of the remaining one-third, two-thirds, or two-ninths of the whole die of consumption, leaving, consequently, only one-ninth to die from other chronic maladies, and from pure old age. How small, then, must be the number of those who expire from decrepitude simply!

2. ACCIDENTAL DEATH.

This term has been used by many physiologists to include all kinds of death that befall man in the course of his career, and before the natural term; the cause consisting in some accidental organic lesion, which arrests the vital movements before they would cease of themselves. This kind of death differs essentially from that which we have been considering. The individual is here, perhaps, in the full possession of all his faculties; his organs have been previously, to all appearance, in the most favourable condition for the prolongation of life; and his death, instead of being natural, and unperceived in its approaches by the individual himself, is usually forced and violent.

Every form of sudden death commences by the interruption of one of the three great vital acts, circulation, respiration, or innervation. One of these functions ceases first, and the others die in succession, or the lethiferous influence, as in poisons acting through the blood—*necræmia*—may affect them all in succession or simultaneously. Each will demand a few remarks.

a. *Death beginning in the Heart.*—When—owing to fatal syncope, to wounds of the heart or great vessels, or to the rupture of an aneurism—the heart is struck with death, the cessation of the functions is speedy. Sensation and motion are lost; respiration is arrested, and death occurs,—if the cause of the cessation of the heart's action be suddenly and sufficiently applied,—almost instantaneously. The order in which death takes place in the different organs is as follows:—The heart failing to propel its blood, the encephalon and gray matter of the medulla spinalis no longer receive the necessary impulse for the continuance of their functions; they therefore cease to act; the consequence of this is the death of all those organs that receive their nervous influence from them; all voluntary motion is annihilated, as well as the action of the respiratory and other reflex muscles; the mechanical phenomena of respiration are, consequently, arrested; and air is no longer received into the chest. From this cause, then, the chemical phenomena of respiration would cease, were they not previously rendered unnecessary by the cessation of the heart's action. The phenomena of nutri-

tion, secretion, and calorification,—functions connected with the intermediate system of vessels,—yield last. Dr. C. J. B. Williams[1] divides death beginning at the heart into two modes—*sudden*, as in syncope, and *gradual*, as in asthenia. In the latter case, however, where the cessation of action of the different organs occurs from want of power, as in exhausting diseases, it is not easy to say, in all cases, which is the first link in the chain of fatal phenomena.

b. *Death beginning in the Nervous Centres.*—This occurs in the encephalon. Owing to the loss of innervation,—as in severe injury done to the head, or the worst attacks of apoplexy,—the sensorial functions first cease, and the individual lies deprived of sensation, volition, and mental and moral manifestation—*coma:*—respiration continues, owing to the reflex nervous system being secondarily affected only: but it becomes progressively more irregular and laborious, and ultimately ceases. The order of death is here as follows:—the interruption of the brain's action destroys first that of the voluntary, and secondly that of the mixed muscles; the mechanical phenomena of respiration therefore cease, and then the chemical. This is followed by cessation of the heart's action, owing to the united loss of nervous influx from the brain, and the want of a due supply of blood. To the cessation of the heart's action succeeds the loss of the general circulation; and lastly, that of the functions of nutrition, secretion, and calorification. It rarely perhaps happens, that death arises from sudden arrest of action of the true spinal or reflex system. In such case, all the muscles, that are animated by this portion of the nervous system, would become at once paralysed.

c. *Death beginning in the Lungs.—Death by Asphyxia* or *Apnœa.*—The action of the lungs may be destroyed in two ways: either the mechanical phenomena of respiration may first cease, as in hanging, strangulation, &c., when air is prevented from reaching the lungs; or the chemical phenomena may be first arrested, as when air is breathed, which does not contain oxygen, but yet can be respired for a time. In the first case, the order of death is as follows:—the mechanical phenomena cease; to this succeeds cessation of the chemical phenomena, owing to the supply of air being cut off; the blood, not experiencing the necessary conversion in the lungs, soon stagnates in the pulmonary capillaries: for a time, however, the heart continues to beat, owing to the aeration effected by the residuary air in the minute bronchial ramifications; but this soon ceases in consequence of defective supply of blood; the nervous centres die, and other parts in succession. When the chemical phenomena cease first, the suspension of the action of the nervous centres, for the cause already assigned, follows; and the mechanical phenomena are not arrested, until the nervous influx is cut off by the death of its organ.

Dr. Williams adds another chief variety of the modes of death,—*Death beginning in the Blood—Necræmia.* In this variety, owing to poisonous influences, as in typhus and other malignant fevers, the life or characters of the blood become annihilated suddenly, or progress-

[1] Principles of Medicine, Amer. edit., by Dr. Clymer, p. 363, Philad., 1844.

ively. Death, however, in this case, must still be occasioned by the lethiferous influence exerted by the blood on one or more of the three great vital functions. In death from exposure of the whole body to a low temperature, there seems to be—as Dr. Carpenter has remarked—a stagnation of all the vital operations of the system.[1]

The immediate phenomena of death and the order of their succession are easily understood, when one of the great centres of vitality is suddenly destroyed, either from accident or disease; but when death does not follow immediately, and time is allowed for a series of morbid phenomena to be established, the problem becomes much more complicated. Some organ or structure is first deranged; and, owing to the intimate connexion, which, as we have elsewhere seen, exists between the various functions, general derangement or irritation follows, and the individual dies, worn out by such irritation, but without our being able to understand on which of the great centres that dispense vitality the malign influence has been exerted, or whether it may not have affected all equally. In inflammation of the brain, heart, or lungs, we may presume that the functions of these organs have been respectively annihilated by the diseased action; and that, as such functions are essential to the existence of vitality, death may arise in the manner already described. But we frequently find the bowels, or the peritoneum lining the interior of the abdomen, affected with inflammation; and the case, if neglected, is as surely attended with fatal consequences as the same morbid affection of organs termed vital; and this in a space of time so short, as not to enable us to understand the nature or mode of action of the lethiferous agent; but that it must exert its influence on one or more of the great centres of vitality is manifest. In many cases, the heart seems to yield first, not suddenly but gradually; the brain, failing to receive its due impulse, becomes progressively unfit for transmitting the nervous influence to the muscles; insensibility by degrees supervenes, until it has attained such an extent, that no nervous influence is sent to the respiratory muscles, when cessation of their action naturally ensues. Of the nature, however, of the morbid condition of the heart thus induced by disease, we are totally ignorant. It is fashionable to say, that death is produced by irritation, but this is merely concealing our deficiency of knowledge under a term, the explanation of the agency of which comprises the whole difficulty. M. Adelon[2] thinks, that the brain generally gives way first in these cases; in consequence of which the respiration is disturbed; the lung becomes engorged; breathing more and more difficult, and death occurs as in a case of gradual asphyxia. There is something extremely obscure in these cases. It often happens, that the intellectual manifestations and nervous distribution to the muscles of voluntary motion are executed, even vigorously, until a short time prior to dissolution, whilst the feeble, irregular, and intermittent beat of the heart may indicate how greatly its irritability is morbidly implicated.

These remarks are chiefly applicable to death as it arises from the numerous acute affections that are so fatal to mankind; but it may

[1] Principles of Human Physiology, Amer. edit., p. 867., Philad., 1855.
[2] Physiologie de l'Homme, 2de édit., iv. 472, Paris, 1829.

occur, also, from those, that persist for a great length of time, and destroy after months or years of morbid irritation, as in cases of calculi of the bladder, engorgements of the viscera, &c. In these cases, likewise, death must ultimately result from the destruction of one or other of the vital functions,—respiration, circulation, or innervation; but in a manner so gradual, that it takes place nearly in the same way as in old age; except that, in all cases, it proceeds from the centre to the circumference, the great internal functions first ceasing, and afterwards their dependencies,—a difference which explains why we are justified in attempting means of resuscitation in sudden death, whilst it would be the height of absurdity to have recourse to them where,

> "Like a clock worn out with eating time,
> The wheels of weary life at last stand still."

The renovation could only be effected by the substitution of new, for the worn out, machinery.

It has been already shown (vol. ii. p. 482), that there are certain causes of death, which affect the two sexes in infancy to a different extent; and the same fact is exhibited when the ratio of deaths of male and female is taken at all ages. The following table, from the valuable statistical report now annually made by the direction of the British government, shows this in a striking manner.[1]

Causes of Death.	Number of Deaths.			
	1838.		1839.	
	Males.	Females.	Males.	Females.
Cancer	620	1,828	660	2,031
Hooping-cough	4,036	5,071	3,683	4,482
Consumption	27,935	31,090	28,106	31,453
Child-birth		2,811		2,915
Violent deaths	8,359	3,368	8,325	3,307
Hydrocephalus	4,242	3,430	4,313	3,436
Diabetes	152	55	151	63
Convulsions	14,549	11,498	14,245	11,163
Delirium tremens	167	15	184	22
Tetanus	100	29	102	20
Bronchitis	1,193	874	916	747
Pleurisy	329	253	342	246
Pneumonia	9,887	8,112	10,000	8,151
Asthma	3,359	2,386	3,092	2,091
Pericarditis	74	50	83	52
Aneurism	88	31	69	33
Hernia	318	189	299	175
Fistula	82	18	81	22
Stone	282	38	274	25
Cystitis	103	25	118	20
Nephritis	113	44	99	32
Gout	161	46	170	45
Dropsy	5,170	7,172	5,268	6,983
Intemperance	125	36	178	40
Starvation by want, cold, &c.	126	41	85	45

[1] Mr. W. Farr, in Third Annual Report of the Registrar-General of Births, Marriages, and Deaths in England, p. 72, Lond., 1841.

The statistical information on this matter, officially obtained in the United States, cannot be depended upon to the same extent as that obtained in Great Britain. The classified and aggregate deaths in the several States for twelve months ending with May, 1850, have been recorded as follows.[1]

STATES.	All causes.	I. Zymotic diseases.	SPORADIC.												
			II. Diseases of uncertain or variable seat.	III. Diseases of brain and nervous system.	IV. Diseases of respiratory organs.	V. Diseases of organs of circulation.	VI. Diseases of digestive organs.	VII. Diseases of urinary organs.	VIII. Diseases of generative organs, and childbirth.	IX. Diseases of locomotive organs.	X. Diseases of the skin.	XI. Old age.	XII. External causes.	XIII. Stillborn.	XIV. Unknown.
Alabama	9,091	3,029	638	676	1,174	34	709	36	151	41	13	176	616	7	1,791
Arkansas	3,021	1,358	122	144	396	6	254	5	62	13	2	39	132	7	481
California	905	659	9	13	15	..	6	..	..	1	1	2	38	..	161
Columbia, Dist. of	846	289	34	89	197	12	37	2	11	8	1	29	33	..	104
Connecticut	5,781	1,987	457	517	1,293	106	195	26	41	39	4	356	240	7	513
Delaware	1,209	461	82	113	190	5	63	1	10	8	..	28	40	..	208
Florida	931	307	97	51	108	8	114	3	21	3	2	25	76	2	114
Georgia	9,925	3,136	912	474	1,334	33	872	31	199	53	16	248	663	29	1,925
Illinois	11,759	5,858	433	712	1,799	32	411	41	167	60	11	107	332	4	1,792
Indiana	12,708	6,331	512	905	1,824	37	414	42	137	64	31	182	361	33	1,835
Iowa	2,044	954	83	147	376	3	67	4	26	6	5	13	100	1	259
Kentucky	15,033	6,895	852	878	2,101	68	588	50	141	75	20	306	569	17	2,473
Louisiana	11,956	5,999	521	861	1,175	50	781	18	135	36	13	170	599	15	1,578
Maine	7,584	2,654	498	492	2,077	76	292	35	58	36	46	310	302	..	708
Maryland	9,621	3,345	496	855	1,792	129	405	22	109	70	11	278	332	17	1,760
Massachusetts	19,404	7,189	1,627	1,296	4,418	335	1,065	59	209	85	66	792	657	24	1,582
Michigan	4,515	1,428	388	483	1,081	30	157	25	74	26	23	109	195	4	492
Mississippi	8,721	3,639	509	570	1,091	45	732	21	130	38	9	126	601	10	1,200
Missouri	12,292	6,832	447	649	1,344	37	555	15	149	56	8	101	371	7	1,721
New Hampshire	4,231	1,582	302	333	1,072	89	140	21	30	27	2	279	146	..	208
New Jersey	6,465	2,512	431	667	1,201	72	268	17	58	51	8	272	231	4	673
New York	45,600	17,976	3,633	4,492	8,913	549	1,906	182	358	262	68	1,393	1,633	51	4,184
North Carolina	10,165	2,495	1,010	527	1,728	28	620	63	188	67	14	409	596	20	2,393
Ohio	28,957	16,138	1,265	1,809	4,025	137	836	92	221	119	29	506	707	6	3,067
Pennsylvania	28,551	11,645	1,919	2,824	5,055	323	957	121	365	193	28	928	954	33	3,206
Rhode Island	2,241	780	164	222	572	31	60	2	15	10	7	97	101	17	163
South Carolina	8,047	2,645	678	467	1,343	30	755	15	150	47	15	263	403	11	1,225
Tennessee	11,875	4,524	733	628	1,493	34	542	42	131	85	26	316	570	29	2,720
Texas	3,057	1,285	150	159	377	11	180	3	73	13	2	34	204	6	560
Vermont	3,129	951	258	267	886	67	100	16	24	11	3	210	93	1	242
Virginia	19,059	5,190	1,427	1,249	3,567	103	925	83	312	133	17	867	942	15	4,229
Wisconsin	2,903	1,242	177	228	541	12	129	7	47	24	1	29	123	..	343
Territories. Minnesota	29	12	2	3	4	..	3	..	..	..	..	..	2	..	3
Territories. New Mexico	1,157	335	120	19	165	2	31	..	32	10	2	26	67	..	348
Territories. Oregon	47	23	1	2	6	1	4	..	1	1	1	..	3	..	4
Territories. Utah	239	149	10	12	35	..	5	1	1	..	..	1	9	..	16

The diagram, Fig. 532, from M. Quetelet,[2] exhibits the relative viability of the two sexes as deduced by him from numerous statistical inquiries. The dotted line represents the viability of the female: the other that of the male. According to this, the maximum of viability is at the age of 14 in both sexes. After puberty, it diminishes more rapidly in the female than in the male. It is also less during the period of childbearing, from the 27th to the 45th year. The age of

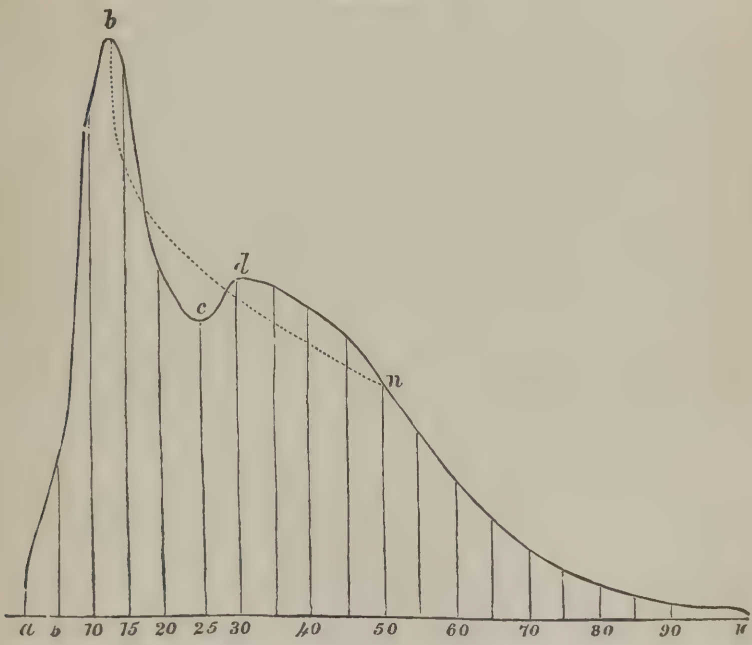
[1] Mortality Statistics of the Seventh Census of the United States, 1850: embracing, 1. The cause of death. 2. The age and sex. 3. The colour and condition. 4. The nativity. 5. The season of decease. 6. The duration of illness. 7. The occupation of the persons reported to have died in the twelve months preceding the first of June of that year; with sundry comparative and illustrative tables. By J. D. B. De Bow, Superintendent United States Census, p. 11, Washington, 1855.

[2] Sur l'Homme, &c., English edit., p. 32, Edinb., 1843.

shortest viability is immediately after birth; that of the longest viability immediately before puberty. The viability of the child after the first month of existence, according to M. Quetelet, is greater than that of the man nearly 100 years old. Towards the 75th year, it is scarcely greater than that of the infant about the sixth month after birth.

For some time before dissolution,—both in death from old age and from disease,—the indications of the fatal event become more and more apparent. The speech grows embarrassed; the ideas are incoherent; the hands, if raised by the effort of the will, fall inertly into their former position; the laboured respiration occasions insufficient hæmatosis, and the distress excites an attempt at respiration, which the debility renders nearly ineffectual; distressing yawnings and gaspings occur to remedy the defective pulmonary action, and the whole respiratory system is in forcible and agitated motion,—the teeth, at times, gnashing, and convulsive contractions occurring at the corners of the mouth. The heart becomes gradually unable to propel the blood with the necessary force into the arteries, so that the fluid ceases to reach the extremities of the body—the hands, feet, nose, and ears—which

Fig. 532.



Curves indicating the Viability or Existibility of Male and Female at Different Ages.

become frigid, and a cold clammy moisture oozes from the vessels. In experiments on animals, the blood is found to be gradually driven no farther than to the feet; then to the groin; afterwards it reaches only to the kidneys, and a kind of reflux occurs through the space along

which it had previously been urged forwards. The flux and reflux now reach no farther than the diaphragm, and gradually retreat, until the blood flows back upon the heart itself, which now stops for a time, and then makes an effort to free itself from the contained fluid. The heart's action and respiration are imperfectly performed for a few times at irregular intervals, until at length the contractility of the organ is entirely gone. Respiration ceases by a strong expulsion of air from the chest,—often accompanied by a sigh or a groan, and probably arising in part from the relaxation of the inspiratory muscles, but still more from the elasticity of the cartilages of the ribs. Hence it is that, in common language, *to expire* is synonymous with *to die*. In cases of sudden death, the heart may continue to beat for a while after innervation and respiration have ceased.

For some time immediately preceding dissolution, there is usually a peculiar mixed expression of countenance,—a compound of apparent mental and corporeal suffering,—which has given occasion to its being called "the *agony*." It is characterized by facial indications, that were first well described by Hippocrates, and from him called *Facies Hippocratica*. The nose is pinched; the eyes are sunken; the temples hollow; the ears cold and retracted; the skin of the forehead is tense; the lips are pendent, relaxed, and cold. The eye, during this condition, especially when dissolution approaches, is fixed and slightly elevated, being kept in that position, according to Sir Charles Bell, by the power of the brain over the voluntary muscles of the eye being lost, and the organ being given up to the action of the oblique, which he considers to be involuntary muscles. The word "agony," applied to this condition, means in many languages a violent contest or strife, but its acceptation has been extended so as to embrace what have been termed the "pangs of death," and any violent pain. This agony of death, however, physiologically speaking, instead of being a state of mental and corporeal turmoil and anguish, is one of insensibility. The hurried and laboured breathing; the peculiar sound on inspiration, and the fixed and turned up eyeball, instead of being evidences of suffering, are now admitted to be signs of the brain having lost all, or almost all, sensibility to impressions. All the indications of mortal strife are such in appearance only; even the convulsive agitations, occasionally perceived, are of the nature of epileptic spasms, which we know to be produced in total insensibility, and to afford no real evidence of corporeal suffering.

Although, from the moment that respiration and circulation permanently cease, the body may be regarded as unquestionably dead, vital properties remain in some of the organs, the presence of which is an evidence that vitality had previously and recently existed. The functions, which persist after the animal has become dead to surrounding objects, are those that belong to the organic class. Absorption is said to have occurred after death, and the beard and hair to have grown. To a certain degree this growth is possible, in parts which, like the pileous system, are nourished by imbibition; but the apparent elongation of the hair may be, in part at least, owing to the shrinking of the integuments. The rectum is very frequently evacuated after dissolution; and cases have occurred where a child has been born by the

contraction of the uterus after the death of the mother. The most marked evidence, however, of the continuance of a vital property after dissolution, is in the case of the muscles, which, as we have mentioned in another place, can be made to contract powerfully on the application of an appropriate stimulus, even for hours after death. Nysten,[1] from his experiments, inferred, that the parts cease to contract in the following order:—the left ventricle, large intestine, small intestine, stomach, bladder, right ventricle, œsophagus, iris, different voluntary muscles, and, lastly, the auricles, particularly the right auricle.

The body cools gradually at the surface, and especially towards the extremities. In many cases, however, instead of gradually cooling, the temperature actually rises. Dr. John Davy[2] had noticed, that after death from fever, the thermometer, placed under the left ventricle of the heart, indicated, in one case, a temperature of 113°; but the temperature before death was not noted, and he was induced to believe, that the elevated temperature was generated before death, and "probably in the same way as the ordinary degree of animal heat, experienced in health, or the extraordinary degree witnessed in febrile diseases." Experiments, however, by Dr. Bennet Dowler,[3] of New Orleans, have satisfactorily shown, that the increased production of heat, which he noticed in yellow fever cases, occurs after the cessation of respiration and circulation, and only ceases with the putrefactive process. In one case, for example, the highest temperature during life was in the axilla, 104°; ten minutes after death it was 109° in the axilla; fifteen minutes afterwards, it was in the thigh 113°; in twenty minutes, the liver gave 112°; in one hour and forty minutes, the heart 109°,—the thigh, in the old incision, 109°; and in three hours after removing all the viscera, a new incision in the thigh gave 110°. It is curious, that the maximum of observed heat after death was in the thigh. The following table by Dr. Dowler exhibits the highest amount of temperature noted in eight different regions in different subjects.

Thigh.	Epigastrium.	Axilla.	Chest.	Heart.	Brain.	Rectum.	Liver.
113°	111°	109°	107°	109°	102°	111°	112°
109	110	109	106·5	106	101	109	109
109	109	108	106	105	101	107	108
109	109	108	106	104	100	107	107
108	109	107	105	104	99	106	106
Mean 109·4	109·6	108·2	106·1	105·6	100·6	108	108·4

It appears from Dr. Davy, Dr. Dowler, and Dr. Benjamin Hensley, jr.,[4] who instituted some observations at the Philadelphia hospital, at the request of the author, that the brain produces less heat after death than the contents of the other splanchnic cavities. The bearing of

[1] Recherches de Physiologie et de Chimie Pathologiques, Paris, 1811.
[2] Researches, Physiological and Pathological, Amer. edit., p. 328, Philad., 1840.
[3] Medical Examiner, June, 1845, cited from Western Journal of Medicine and Surgery, June and October, 1844.
[4] Medical Examiner, March, 1846, p. 149.

these phenomena on the explanation of calorification has been noticed elsewhere.

Another remarkable phenomenon, noticed by Dr. Dowler[1] in yellow fever subjects especially, "which are incomparably the best for study," is what he has termed "post-mortem contractility." Numerous experiments were performed by him on bodies, that had been dead from a few minutes to several hours, in which the muscles of the extremities, struck with a cane, billet of wood, the hand, or the side of a hatchet, contracted with sufficient force to move a weight of several pounds, and he found, that if several blows on the same spot followed each other rapidly, there was but one contraction, but they exhausted the contractile function more than a single blow; "and if the force be greatly augmented the contractility may be killed, almost immediately in the muscle struck, without impairing the action of any other part." Spontaneous movements of the limbs have frequently been observed in persons who have died from cholera.[2]

Whilst the refrigeration of the body is going on, the blood remains more or less fluid; and owing to the arteries emptying themselves, by virtue of their elasticity, of their contained blood, it generally accumulates in the venæ cavæ, auricles of the heart, and vessels of the lungs. By virtue of its gravity, it collects also in the most depending parts, occasioning cadaveric hyperæmia, suggillations or livid marks, which might be mistaken for bruises inflicted during life; but may generally be distinguished from them by attention. It will be readily understood, that the situation of the blood in the vessels may differ somewhat according to the vital organ which first ceases its functions. If the action of the right heart stops, the lung may be empty; if the lung or left heart ceases, the lung and right side of the heart—with the vessels communicating with it—may be surcharged with blood, whilst the organs of the corporeal circulation may be almost empty. During the progress of refrigeration, and especially soon after death, the muscles are soft and relaxed, so that the limbs fall into the position to which the force of gravity would bring them; the eyes are half open; and, according to a recent writer, M. Rippault[3]—the iris is perfectly flaccid when the globe of the eye is compressed in two opposite directions; and if the person be alive the pupil will retain its circular form notwithstanding the compression; whilst if dead, the aperture becomes irregular and the circular form is lost; the lips and lower jaw are pendent, and the pupil dilated. When the body, however, is cold, the blood is coagulated, and white or yellowish coagula exist in the right heart, which were at one time supposed to be morbid and termed *polypi*. They take the shape, more or less, of the cavity in which they are found.

Lastly, the muscles become firmly contracted, so that no part can be moved without the application of considerable force; and, in this state, they continue until the natural progress towards putrefaction again

[1] Experimental Researches on the Post-mortem Contractility of the Muscles, with Observations on the Reflex Theory, reprinted from the New York Journal of Medicine, for May, 1846.

[2] See Dr. Brown-Séquard, on Spontaneous Rhythmical or Irregular Contractions in Muscles after death, in Medical Examiner, p. 493, August, 1853.

[3] Cited in London Medical Gazette, May, 1846.

softens their fibres. This has been regarded by some physiologists as arising from the last exertion of that residue of vital power, which the body retains after the period of apparent dissolution. With more propriety, perhaps, the *rigor mortis* may be assigned to physical alterations taking place in the organs, owing to the total loss of those powers, which were previously antagonistic to such changes. It has been attributed, by M. Brücke,[1] to the coagulation of the liquids in the interior of the tissues. He considers, that the fibrin of the muscle coagulates, when the muscular fibre is deprived of life. By some, the muscular contraction, which gives occasion to the *rigor mortis*, is held to be of the same kind as that which takes place under the influence of the nervous stimulus, although differing as to its conditions. When very strong, it renders the muscles prominent, as in voluntary contraction; and Dr. Carpenter[2] thinks the comparative observations of Mr. Bowman upon the state of muscular fibre passing into this condition, and upon that which presented various degrees of contraction from ordinary causes, leave no doubt as to their correspondence. The conditions are certainly, however, very different; for the power of the muscle to contract on the application of appropriate stimuli is lost when the rigor mortis sets in. It has also been likened to the coagulation of the blood in the vessels; and Dr. Carpenter[3] thinks "there is certainly evidence enough to make it appear, that some analogy exists between the two actions, although they are far from being identical. After those forms of death in which the blood does not coagulate, or coagulates feebly, the rigidity commonly manifests itself least, but this is by no means an invariable rule." He thinks it probable, "that as the coagulation of the blood is the last act of its vitality, so the stiffening of the muscles is the expiring effort of theirs." Yet—as we have before seen—the rigor mortis can be removed by the injection of blood into the vessels of the part, which appear rather to be in a state of suspended animation, a condition speedily induced by certain agents. Chloroform, for example, injected into the main artery of a limb, instantly produces the strongest rigidity, which disappears if blood be allowed to circulate again in it; and M. Brown-Séquard[4] has found, that if a limb, into which an injection of chloroform has been thrown, is separated from the body, it is able, under the influence of an injection of blood, to recover its muscular irritability, two, three, four, five, and—in one case—ten days afterwards. M. Robin suggests, and M. Brown-Séquard agrees with him, that chloroform prevents the chemical changes that take place in organic bodies after death, and thus it can be understood, how an injection of blood may be able to elicit irritability so long after the limb has been separated from the body. The latter named gentleman, however, found, that chloroform does not entirely prevent organic change in the muscles, as he found that the longer the limbs had been separated from the body, the greater was the quantity of blood necessary for the reproduction of irritability.

[1] Müller's Archiv., Nov., 1842; cited in Edinb. Med. and Surg. Journ., Oct., 1843, p. 492.

[2] Principles of Human Physiology, 2d edit., p. 324, Lond., 1844.

[3] Principles of Human Physiology, 5th Amer. edit., p. 332, Philad., 1853.

[4] Medical Examiner, May, 1853, p. 285.

It might seem from the previous enumeration of the signs of death, that no difficulty could possibly arise in discriminating between a living and a dead body. Cases have, however, occurred, where such difficulty has been great and perplexing. Many of the signs may exist, and yet the person be merely in a state of suspended animation; and in certain instances it has even been considered advisable to wait for the manifestations of the putrefactive process, before the body should be consigned to the grave. The following cases, given by Dr. Gordon Smith,[1] strongly exhibits the embarrassment that may occasionally occur. A stout young man had been subject to epilepsy, which became combined with madness. On this account it was necessary to remove him to a private asylum in the neighbourhood of London, where he died suddenly in a violent epileptic paroxysm. The body was removed to the residence of his friends soon after death, when the necessary preparations for interment were made. On paying attention to the corpse it was found, that the limbs were pliable; that the eye was neither collapsed nor glazed; and that the features retained their full natural appearance as during life. A surgeon, who, for years, had been in the habit of attending him, was sent for; and although he could find no indications of vitality, he prudently recommended, that the interment should not take place until decomposition had began to manifest itself. In the course of two or three days, appearances still continuing the same, a physician was called in, who concurred in the recommendation that had been given. Fifteen days from the supposed time of his death had elapsed, when Dr. Smith's informant had an opportunity of inspecting the body. At this time, the countenance retained the appearance described, but the eye seemed beginning to sink, and some degree of lividity had commenced on the surface of the abdomen. The joints were still flexible. At this time, an eminent professor of anatomy viewed the body, and, considering the hesitation that had prevailed to be altogether groundless, he appointed the following day to examine it internally. The head was accordingly opened, and a considerable extravasation of blood was found in the posterior part of the cranium, between the skull and dura mater, and between the membranes and substance of the brain. No serum was detected in the ventricles; but the brain itself was remarkably hard. This was sixteen days after death. On the following day, the body was interred. A clamour now arose amongst the neighbours, that he had been prematurely handed over to the anatomist. The body was exhumed; an inquest was held; and the evidence of the medical gentlemen demanded. The jury returned a verdict of "apoplexy."

It may hence become a matter of medico-legal inquiry to verify the existence of death, in cases where doubt prevails owing to the person being in a state of apparent death,—natural or assumed. The recent observations and experiments of M. Bouchut[2] lead him to conclude, that all varieties of apparent death, and especially such as are owing to syncope and asphyxia, however much their symptoms may differ, present the common character of the persistence of the heart's pulsation

[1] The Principles of Forensic Medicine, 3d edit., p. 540, Lond., 1827.

[2] Abeille Médicale, No. 6, Juin, 1848.

audible to auscultation. M. Bouchut's communication was laid before the *Académie des Sciences*, of Paris, who awarded him a prize for the same; and the commission to whom it was referred reported, through M. Rayer, a great variety of additional observations made by them, which confirm the conclusions of M. Bouchut. He enumerates the certain signs of death under two divisions—immediate and remote. The *immediate* signs are—prolonged absence of the sounds of the heart; simultaneous relaxation of the sphincters; and sinking of the globe of the eye, with loss of the transparency of the cornea; the first of which is regarded by the commission as conclusive. The *remote* signs are—cadaveric rigidity; absence of muscular contractility under the influence of galvanism, and putrefaction. Yet resuscitation *may* occur a considerable time after the sounds of the heart have ceased to be audible; and perhaps the most singular case on record of suspension of two of the most important of the vital functions occurred in the person of John Hunter. In the year 1769, being then forty-one years of age, of a sound constitution, and subject to no disease except a casual fit of the gout, he was suddenly attacked with a pain in the stomach, which was speedily succeeded by apparently a total suspension of the action of the heart and lungs. By a violent exertion of the will he occasionally inflated the lungs, but over the heart he had no control whatever; nor, although he was attended, from the first, by four of the chief physicians in London, could the action of either be restored by medicine. In about three-quarters of an hour, however, the vital actions began to return of their own accord, and in two hours he was perfectly recovered. "In this attack," says one of his biographers—Sir Everard Home—"there was a suspension of the most material involuntary actions: even involuntary breathing was stopped; while sensation, with its consequences, as thinking and acting, with the will, were perfect, and all the voluntary actions were as strong as ever."[1]

Dr. Bennet Dowler[2] objects to the validity of the tests of M. Bouchut. "Comparative physiology"—he remarks—"shows that an animal may live hours without the heart, and the heart for days without the body. An alligator's heart will act with regularity for many hours, perhaps for days, after having been cut out of the body, and emptied of its blood. Let an alligator, thus deprived of its heart, be roasted; return its heart, and apply the stethoscope, and then the dead will afford this certain sign of life. The commission of the Academy cannot object to this argument, because they themselves experimented on the inferior animals in testing M. Bouchut's claims." Dr. Dowler prefers the test of "post-mortem contractility," as he calls it. Yet we have seen that after the muscular contractility has been lost, it may be restored by injections of oxygenated blood into the vessels of the part.

At one period it was universally credited, that substances could be administered which might arrest the vital functions, or cause them to

[1] Ottley's Life of John Hunter, Bell's Med. Lib. edit., p. 38, Philad., 1839; and Hunter, On the Blood, by Palmer, Bell's edit., p. 189, Philad, 1840. In the latter work, Mr. Hunter refers to his own case.

[2] Researches on the Natural History of Death, New Orleans, 1850.

go on so obscurely as to escape detection. This erroneous popular notion is exhibited in the description of the action of the drug administered by Friar Lawrence to Juliet.

> "Take thou this phial, being then in bed,
> And this distilled liquor drink thou off;
> When presently thro' all thy veins shall run
> A cold and drowsy humour, which shall seize
> Each vital spirit: for no pulse shall keep
> His natural progress, but surcease to beat.
> No warmth, no breath, shall testify thou liv'st;
> The roses in thy lips and cheeks shall fade
> To paly ashes; the eyes' windows fall
> Like death, when he shuts up the day of life;
> Each part, deprived of supple government,
> Shall stiff, and stark, and cold, appear like death:
> And in this borrowed likeness of shrunk death,
> Thou shalt remain full two-and-forty hours,
> And then awake as from a pleasant sleep."
>
> *Romeo and Juliet*, iv. 1.

Death may be feigned for sinister purposes. When the author was in attendance on the lectures of Mr. Brookes, the distinguished anatomist of London, a body was brought in a sack to the house, the vitality of which was detected by the warmth of a protruded toe. It was that of a robber, who had chosen this method of obtaining admission within the premises.

The celebrated case of Colonel Townshend, as well as that of Dr. Cleghorn, referred to elsewhere,[1] exhibits the voluntary power occasionally possessed over the vital functions, and curious cases are related by Mr. Braid[2] of the Fakeers in India, which lead to the belief, that it is possible for the organic actions to be so reduced, that no sign of life may be perceptible for days, and even weeks; and yet that the subjects may be subsequently restored. Some of the cases, given by Mr. Braid, the authenticity of which is vouched for by British officers of high rank in India, would be incredible, without such authority. If believed, they lead to the inference—as Mr. Braid has suggested—that a condition resembling the hibernation of animals is possible in the human subject. In one case, the Fakeer was buried in a subterranean cell, which was well guarded for six weeks: in another, the man had been buried for ten days in a grave lined with masonry, and covered with large slabs of stone; and in another, the experiment was made for three days, under the superintendence of a British officer. In every case, it is affirmed, the body resembled that of a dead person, and no pulsation was perceptible anywhere; yet under the application of warmth to the vertex, and of friction to the body and limbs, restoration was accomplished. Dr. Carpenter[3] observes on these strange cases:—"It may be remarked, that the possibility of the protraction of such a state (supposing that no deception vitiates the authenticity of the narratives referred to) can be much better comprehended as occurring in India, than as taking place in this country [Great Britain]; since

[1] Vol. i. 403.
[2] Observations on Trance or Human Hibernation, London, 1850.
[3] Principles of Human Physiology, Amer. edit., p. 868 (note), Philad., 1855.

the warmth of the tropical atmosphere and soil would prevent any serious loss of heat, such as must soon occur in a colder climate, when the processes whereby it is generated are brought to a stand." Yet there is reason to believe, that where the organic actions are reduced to a low point, the absence of heat of a certain degree is desirable.[1] It has been before remarked,[2] that fishes, which have been frozen for thirty-six hours, have been resuscitated; and Dr. Kane related to the author some strange, but authentic, cases of restoration amongst the Esquimaux, where persons had been considered dead, and buried in the snow many hours.

Lastly, the character of the death, as to violence or gradual extinction, is often exhibited in the physiognomy of the dead. Where it has taken place during a convulsion, or by agents that have forcibly and suddenly arrested respiration or innervation, the countenance may be livid; the jaws clenched, the tongue protruded and caught between the teeth, and the eyes forced, as it were, from their sockets; but usually in death from old age, or even from acute and tormenting disease, any distortion or mark of suffering that may have existed prior to dissolution subsides after the spirit has passed, and the features exhibit a placidity of expression singularly contrasting with their previously excited condition. For effect, however, the poet and the painter suit their descriptions of death to the character of the individual whom they are depicting.[3] The tyrant falls convulsed and agonized, whilst the tender and delicate female is described to have progressively withered, till

> "At last,
> Without a groan, or sigh, or glance to show
> A parting pang, the spirit from her past;
> And they who watched her nearest could not know
> The very instant, till the change that cast
> Her sweet face into shadow, dull and slow,
> Glazed o'er her eyes—the beautiful, the black,—
> Oh! to possess such lustre, and then lack."
>
> BYRON'S *Don Juan*, canto iv.

Warwick's description of the frightful physiognomy of Duke Humphrey after death from suffocation exhibits some of this poetical license:—

> "But see, his face is black and full of blood;
> His eyeballs farther out than when he lived,
> Staring full ghastly like a strangled man:
> His hair uprear'd, his nostrils stretched with struggling:
> His hands abroad displayed, as one that grasp'd
> And tugg'd for life, and was by strength subdued.
> Look on the sheets; his hair you see is sticking;
> His well-proportioned beard made rough and rugged,
> Like to the summer's corn by tempest lodged.—
> It cannot be but he was murdered here:
> The least of all these signs were probable."
>
> *King Henry VI.*, Part ii. Act 3.

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[1] See the observations of Mr. Edwards on asphyxied animals, p. 613 of the first volume of this work.

[2] Vol. i. p. 595, and vol. ii. p. 716.

[3] Sir C. Bell, The Anatomy and Philosophy of Expression, 3d edit., p. 185, Lond. 1844.

How different is this picture from that of the countenance of the young being, who has gradually sunk to death in the manner above described. The beauty is unextinguished, and the paleness and lividity of death have taken the place of the colours of life; yet the wonted physiognomy may remain:—

> "Hush'd were his Gertrude's lips! but still their bland
> And beautiful expression seem'd to melt
> With love that could not die!"
>
> CAMPBELL.

Perhaps one of the most beautiful and accurate pictures, drawn by Byron, is his description of the serenity of countenance observable in most fresh corpses; an expression which, by association, is deeply affecting, but not without its consolation to the friends of the departed:—

> He who hath bent him o'er the dead
> Ere the first day of death is fled;
> * * * *
> Before decay's effacing fingers
> Have swept the lines where beauty lingers;
> And marked the mild angelic air,
> The rapture of repose that's there;
> The fix'd yet tender traits, that streak
> The languor of the placid cheek;
> And but for that sad, shrouded eye,
> That fires not,—wins not,—weeps not now;
> And but for that chill, changeless brow,
> Where cold obstruction's apathy
> Appals the gazing mourner's heart,
> As if to him it could impart
> The doom he dreads, yet dwells upon:
> Yes, but for these and these alone,
> Some moments, ay, one treach'rous hour,
> He still might doubt the tyrant's power.
> So fair, so calm, so softly seal'd,
> The first, last look by death revealed.
>
> BYRON'S *Giaour*.

An easy death—euthanasia—is what all desire; and fortunately, whatever may have been the previous pangs, the closing scenes, in most ailments, is generally of this character. In the beautiful mythology of the ancients, Death was the daughter of Night, and sister of Sleep. She was the only divinity to whom no sacrifice was made, because it was felt that no human interference could arrest her arm; yet her approach was contemplated without any physical apprehension. The representation of Death as a skeleton covered merely with skin on the monument at Cumæ was not the common allegorical picture of the period. It was generally depicted on tombs as a friendly genius, holding a wreath in his hand, with an inverted torch,—a sleeping child, winged, with an inverted torch, resting on his wreath; or as Love, with a melancholy air, his legs crossed, leaning on an inverted torch,—itself a beautiful emblem of the gradual self-extinguishment of the vital flame.[1] The disgusting representations of Death from the contents of the char-

[1] D'Israeli, Curiosities of Literature, 2d Series, Amer. edit., vol. ii. p. 44, Boston, 1834.

nel house would not seem to have been common until the austerity of the 14th century, and are beginning to be abandoned. In more recent times, Death has been portrayed as a beautiful youth, and it is under this form that he is represented by Canova on the monument erected in St. Peter's at Rome, by George the Fourth of England, in honour of the Stuarts.

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i. refers to the first, and ii. to the second, volume.

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